Distributed Power, Renewables, Stored Energy and the Grid
Blinkless® Inverter System
Capabilities and Applications:

Gary Gengenbach - Blinkless Power Equipment, LLC.

Several initiatives have been undertaken in the past few years to increase the amount of renewable or other non-hydrocarbon based energy inputs to the grid; the primary players in the initiative are nuclear, solar and wind. Nuclear has the advantage of very large power outputs and a more traditional interface with the existing electrical infrastructure. Nuclear power plants also operate in the same way as coal fired plants in that steam energy is used to turn turbine generators in a controlled fashion so that the electrical output is at a nominal frequency and voltage.

Wind and solar generation systems, or renewables, tend to produce smaller amounts of power in an uncontrolled fashion. The power generated is related to the environment and the system inputs, i.e. with higher wind, windmills run at higher speeds or frequency, and with brighter sun, solar systems increase in DC voltage. The smaller power outputs, and lower costs, of renewables can be turned into an advantage by creating distributed power generation systems, which are large numbers of small generators spread out over a geographic area. This type of distributed system particularly those coupled with an energy storage device such as a battery can reduce loads on the grid and maximize renewable energy usage while greatly reducing energy losses in power transmission lines.

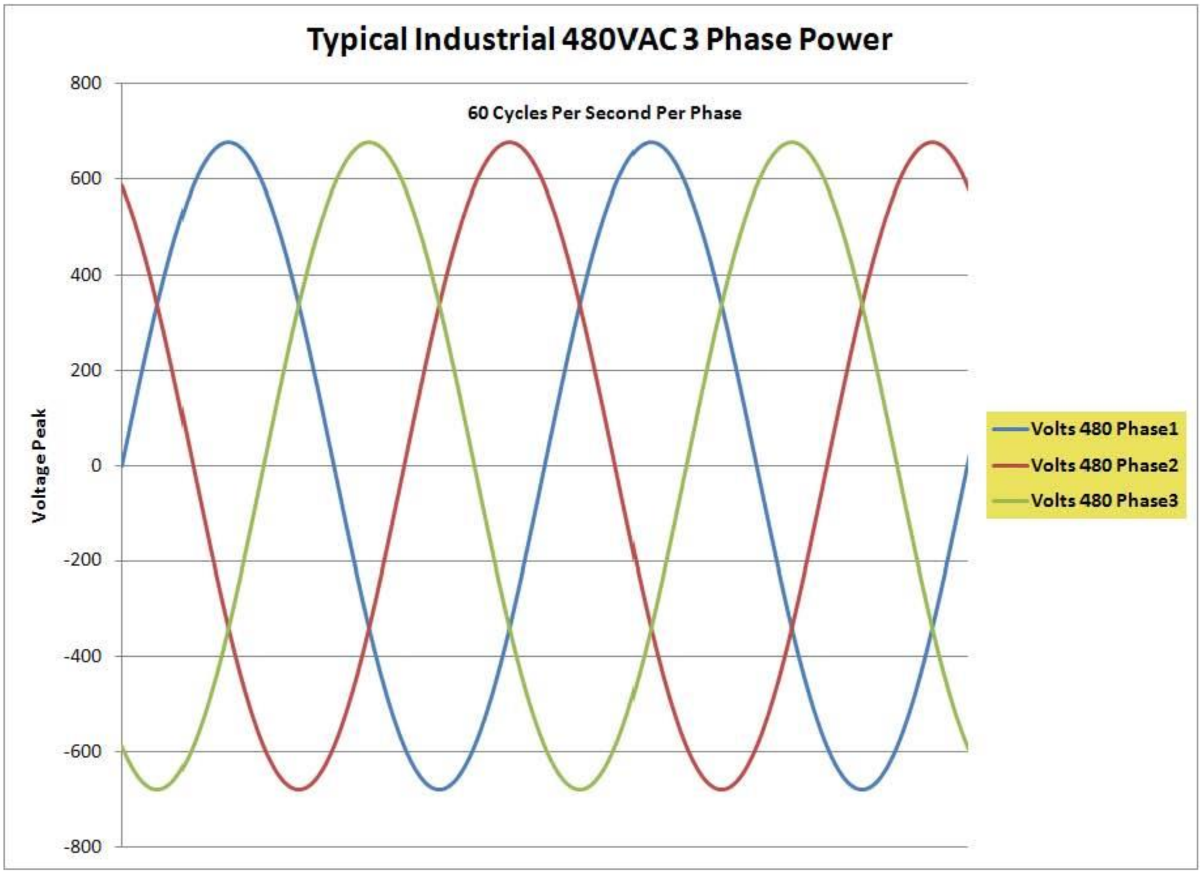
Batteries by themselves can provide advantages by shifting power usage from low usage times (charging the batteries) to high usage times (discharging the batteries). This time shifting strategy can benefit the end user by lowering overall electric costs and the utility by helping to level the usage profile throughout the day.

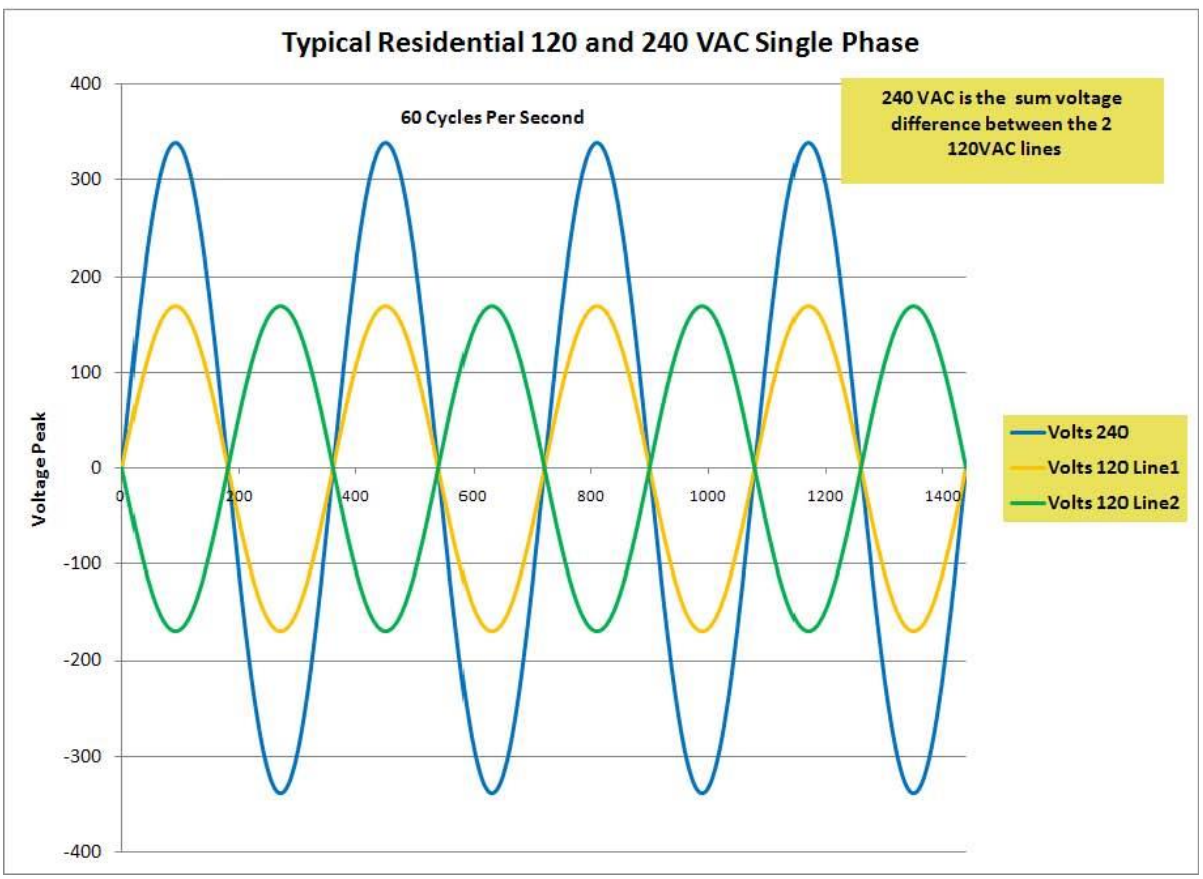
Uncontrolled systems require conditioning to interface with the grid, such as frequency, voltage and phase angle correction. This conditioning is done through the use of power electronics.

Power electronics, inverters in this case, use solid state switches and computer control to alternate the direction of current flow in a circuit. This switching mechanism allows an inverter to create an AC output, like the grid, from a DC input, like a battery. Because the output of the inverter is digitally controlled, it can run at very precise frequencies and voltages, thus it is able to match its output exactly to the grid (grid parallel), or generate an output that mimics the grid (grid isolated).

The following discussion specifically concerns the functionality, applications and benefits of the Blinkless® inverter system. Covered topics include the intertie of renewables to the grid, UPS style functions, peak shaving, and load shifting with storage and micro grids.

The electrical utility, or the grid, in the U.S. operates at a nominal frequency of +/-60Hz; Nominal 3 phase voltages of 480, 230 and 208 VAC, and nominal single phase voltages of 240 and 120 VAC are common. The following charts detail typical 3 phase (industrial) and single phase (residential and light commercial) grid interfaces.


Typical Industrial 480VAC 3 Phase Power
60 Cycles Per Second Per Phase
Voltage Peak
800
600
400
200
0
-200
-400
-600
-800
Volts 480 Phase1
Volts 480 Phase2
Volts 480 Phase3


Typical Residential 120 and 240 VAC Single Phase
60 Cycles Per Second
240 VAC is the sum voltage difference between the 2 120VAC lines
Voltage Peak
400
300
200
100
0
-100
-200
-300
-400
0
200
400
600
800
1000
1200
1400
Volts 240
Volts 120 Line1
Volts 120 Line2

Blinkless® Power System Description and Synopsis of Control Architecture

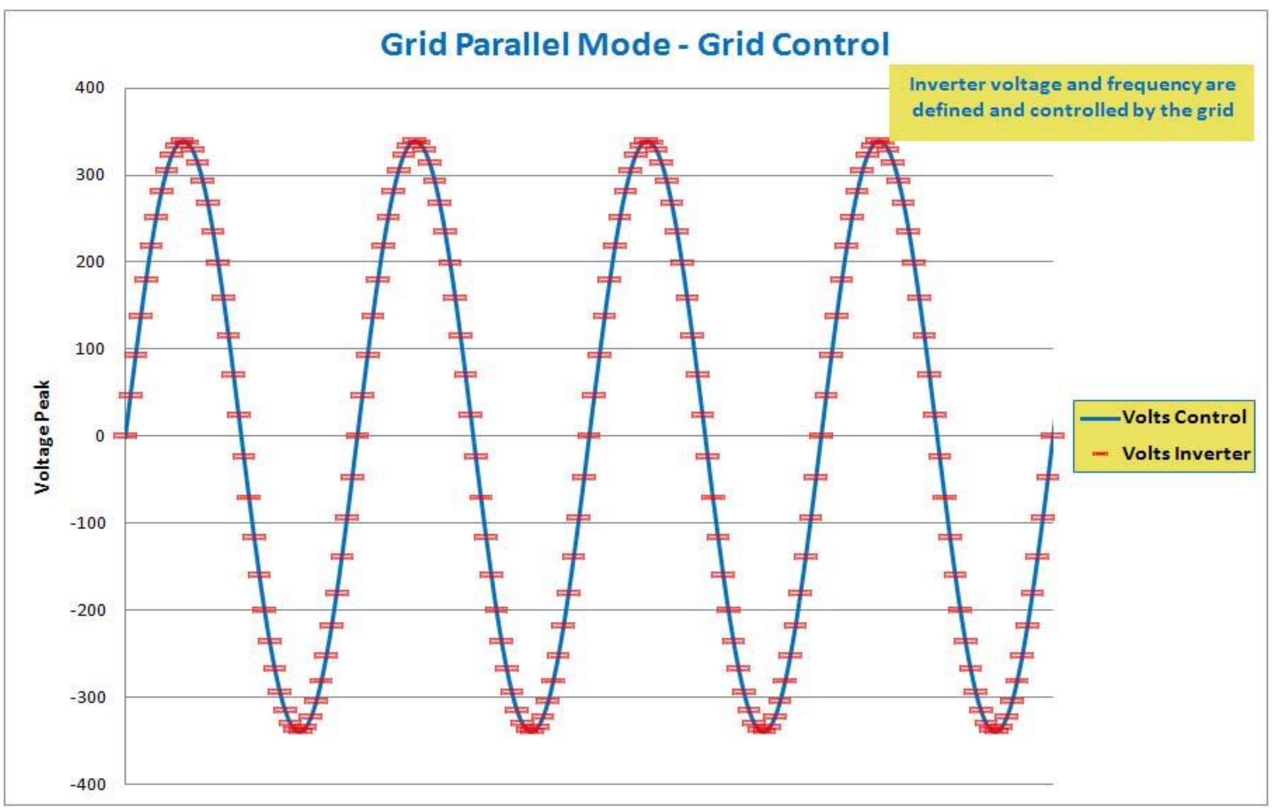
The Blinkless® Inverter System incorporates proprietary technology to provide AC electrical power at the correct frequency, phase and voltage from various AC and DC sources. Blinkless® operates in two distinct modes; grid parallel and grid isolated.

Blinkless® automatically senses the presence of the site source; the grid, a generator, or another inverter, etc. and will switch its control state (grid connected or grid isolated) accordingly. Blinkless® will shut down in accordance to UL1741 and IEEE1547 standards when certain safety parameter limits are exceeded; current, voltage, frequency or temperature.

Blinkless® Grid Parallel Mode

When the system is hooked to, exactly matched to and controlled by the grid, it is said to be in grid parallel mode. In grid parallel mode Blinkless® provides AC electrical power at the correct frequency, phase and voltage when parallel with a site source. Power-factor correction is also provided for increased site electrical efficiency.

The parallel mode is used to help smooth out jolts and spikes to the system and provides peaking power from stored energy at the point of use for longer time frames to help 'load level', or time shift the energy from the grid. Energy is supplied by storage batteries, renewables, on site generators or even from the grid. The parallel mode allows for the introduction of energy from renewable sources to reduce the demand on the grid. The parallel mode is also the connection mode for blink less uninterrupted power supply, (UPS) style backup systems so the system is always monitoring the grid state.

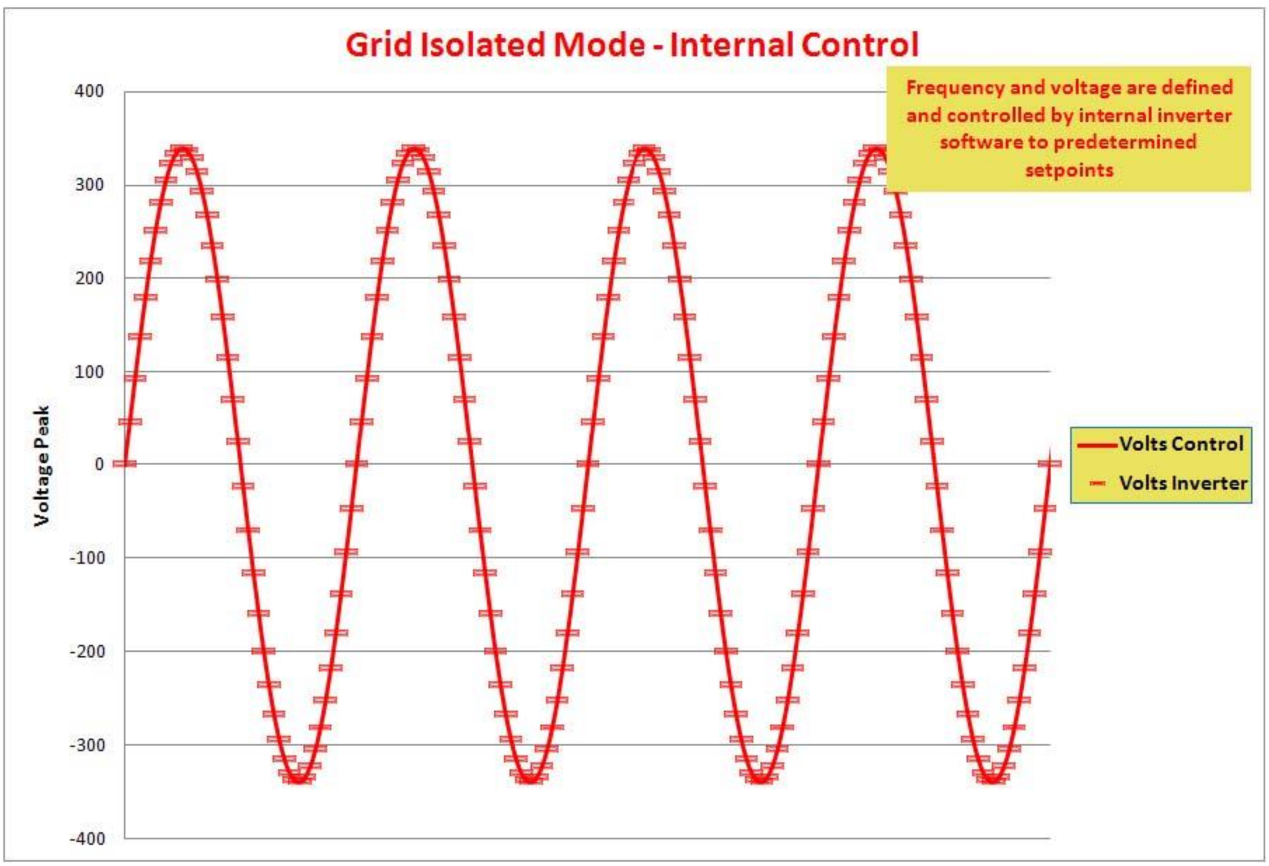


****Note the blue control line in the graph**

Blinkless® Grid Isolated Mode

When it is disconnected from the grid and its output is internally controlled and mimicking grid parameters it is said to be in grid isolated mode. In isolated mode, the system uses an internal digitally produced 60.00Hz, (or 50.00Hz), fundamental frequency. The voltage is controlled to preset values and the current is limited by both the maximum nominal capability of the inverter and the available power from input sources. Energy is supplied by storage batteries, renewables and/or with onsite generators.

While the isolated mode can be used in a full off grid application, the isolated mode is generally regarded as a non-standard mode, i.e. a utility outage. This mode is the control state if the system is functioning as a UPS, carrying critical loads in the event of a grid power failure. The other main use of the isolated mode is the formation of a micro grid, where the main grid is not present and one or more Blinkless® inverters are forming a very small scale grid. The initial Blinkless® module or generator would establish the micro grid voltage and frequency for the additional Blinkless® modules to follow.



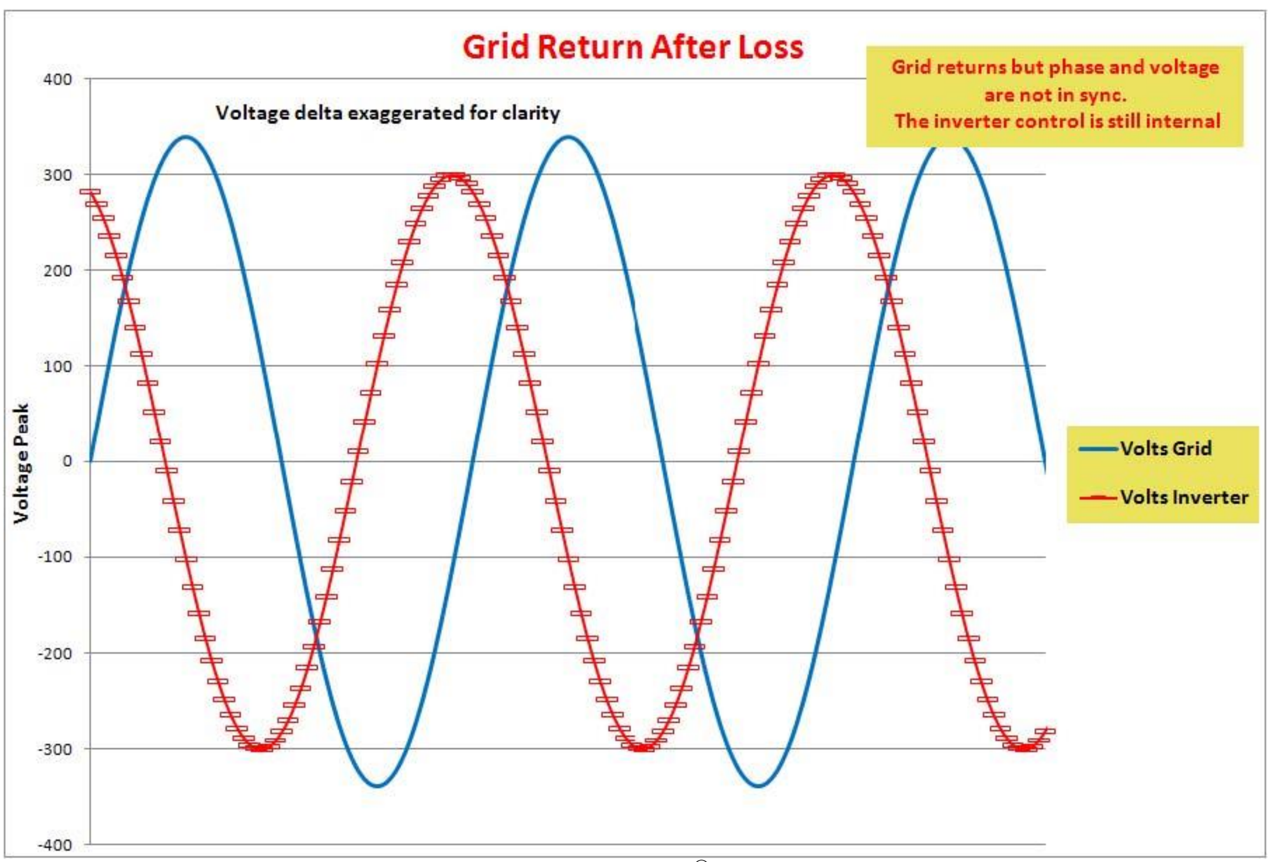
****Note the red control line in the graph**

Blinkless® Source Power Transitions

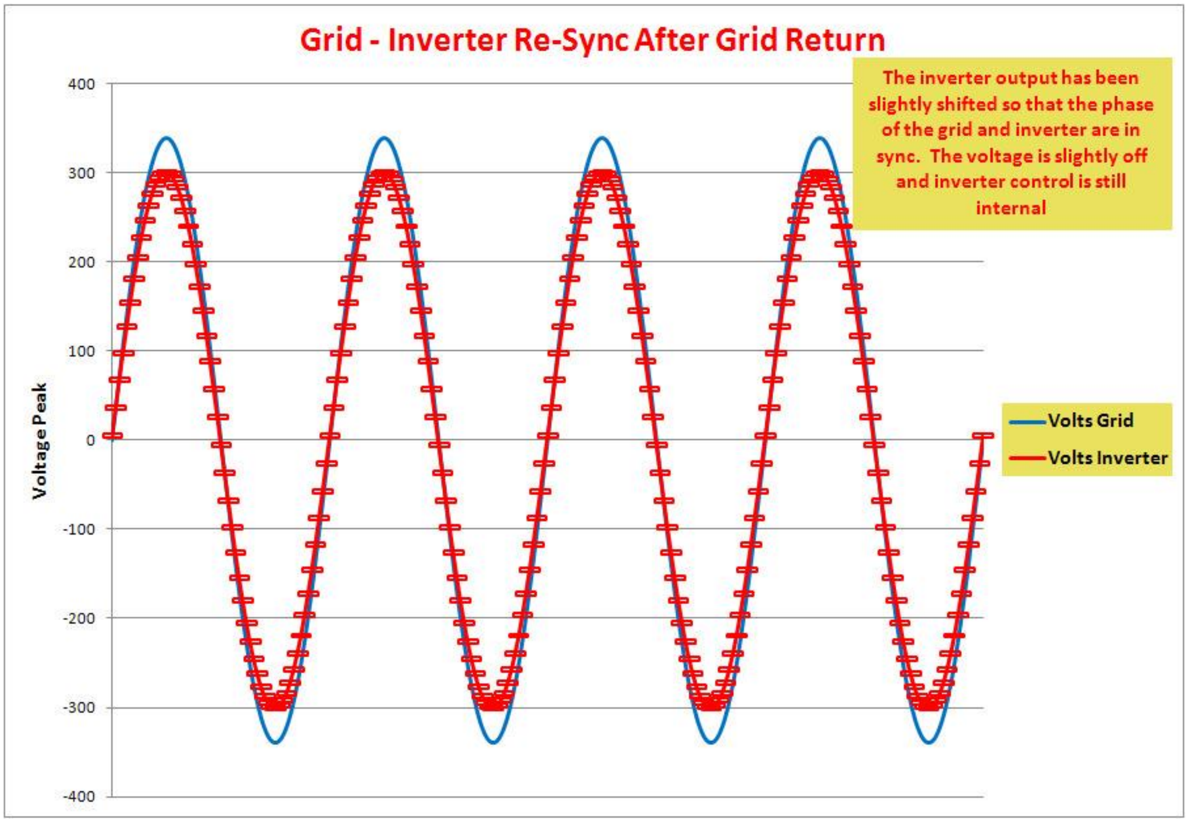
Typical inverters used for renewable energy conversion or UPS functions operate in grid tied mode, they require the grid to function properly. Inverters and generators can cause serious safety hazards to utility workers by electrifying circuits that are believed to be open. Grid tied systems offer a cost effective way to ensure that the inverter is not supplying electrical power to the grid after a grid loss. While this is a cost effective way to ensure compliance with utility safety requirements, it also results in a loss of electrical power every time the grid experiences an outage.

One of Blinkless's key features is that the transition between grid parallel and grid isolated is achieved with a Blinkless® transfer, normally defined by IEEE1547 as less than 2 cycles of the fundamental frequency. Blinkless® achieves a 'perfect' zero time between the two states. The only measurable changes in the AC electrical power output are minor shifts in the frequency and voltage. As long as the attached loads are within the inverter output specifications, and the input energy sources can supply the required power then the lights never go out. The utility safety requirements are met using multiple circuit breakers and a closed loop feedback driven logic structure to control the connections of the Blinkless® system to the grid.

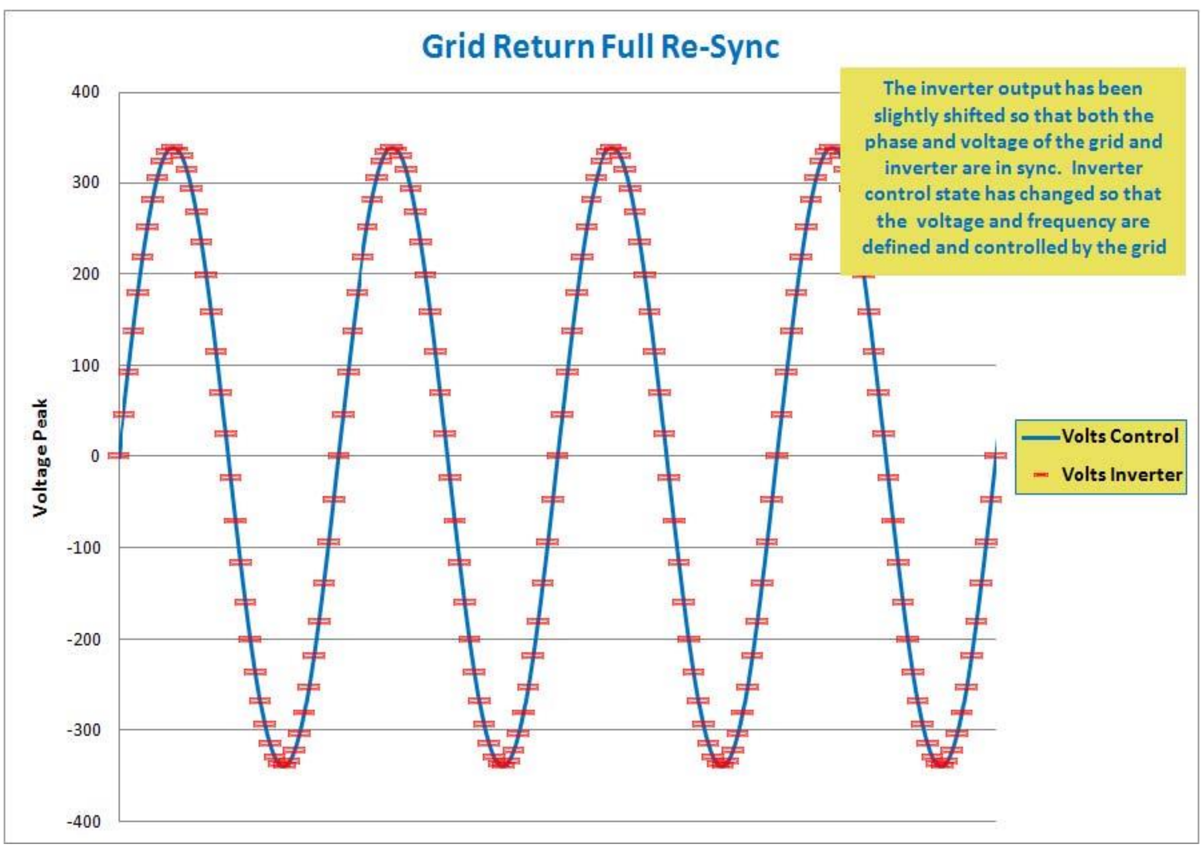
When the grid is lost, the system breaks the physical connection to the grid and automatically changes control states from external, (parallel) to internal, (isolated), the output power is also automatically adjusted to account for the power that was being supplied by the grid. Since the output of the inverter never stopped, the load never saw a 'blink' from the grid loss. When the grid returns it will have an arbitrary phase and voltage error to the inverter system; this grid return and phase error are sensed by the system and a series of events automatically occur to resynchronize the site power to the grid. A connection cannot be made with the error present otherwise an overload will occur – blown fuses or circuit breakers.



****Note the phase and voltage offsets in the graph Blinkless® adjusts its output to match the grid**

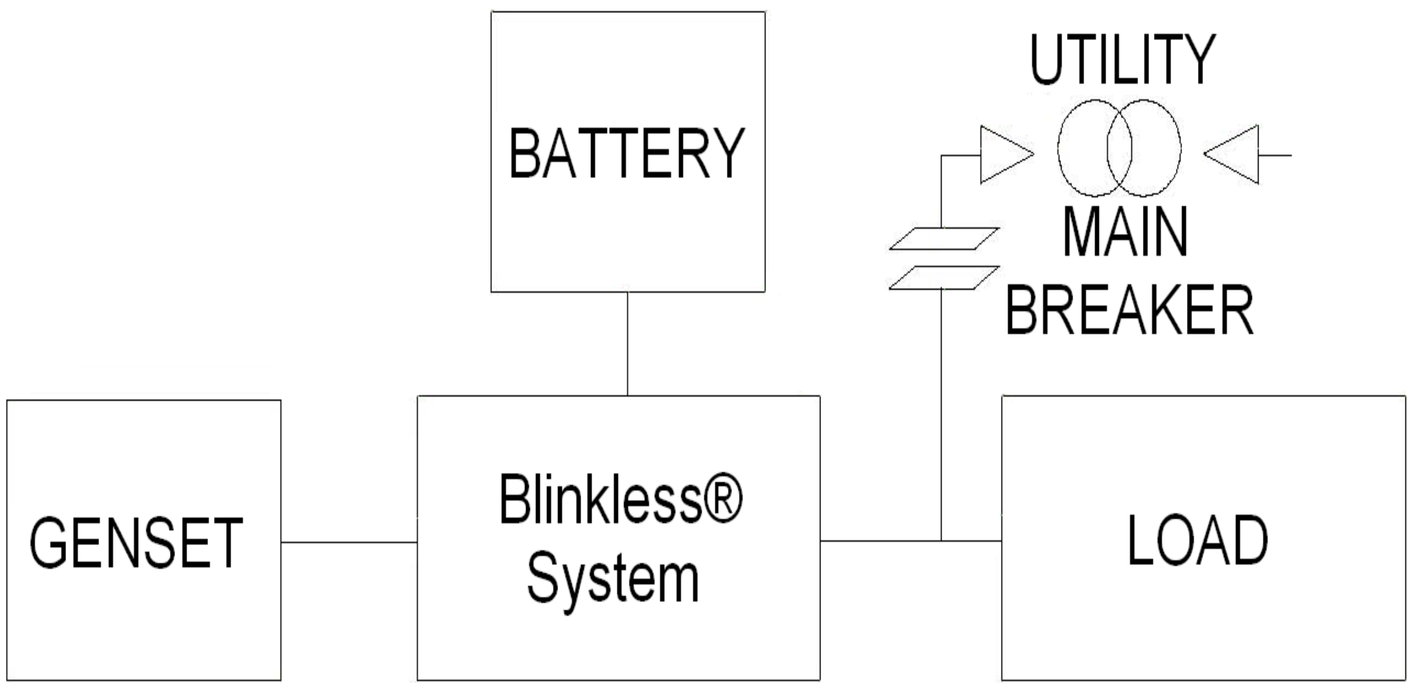


After the sync functions are complete, the inverter control switches back to the grid. The systems are now in full phase and voltage sync; the physical connection to the grid is reestablished.



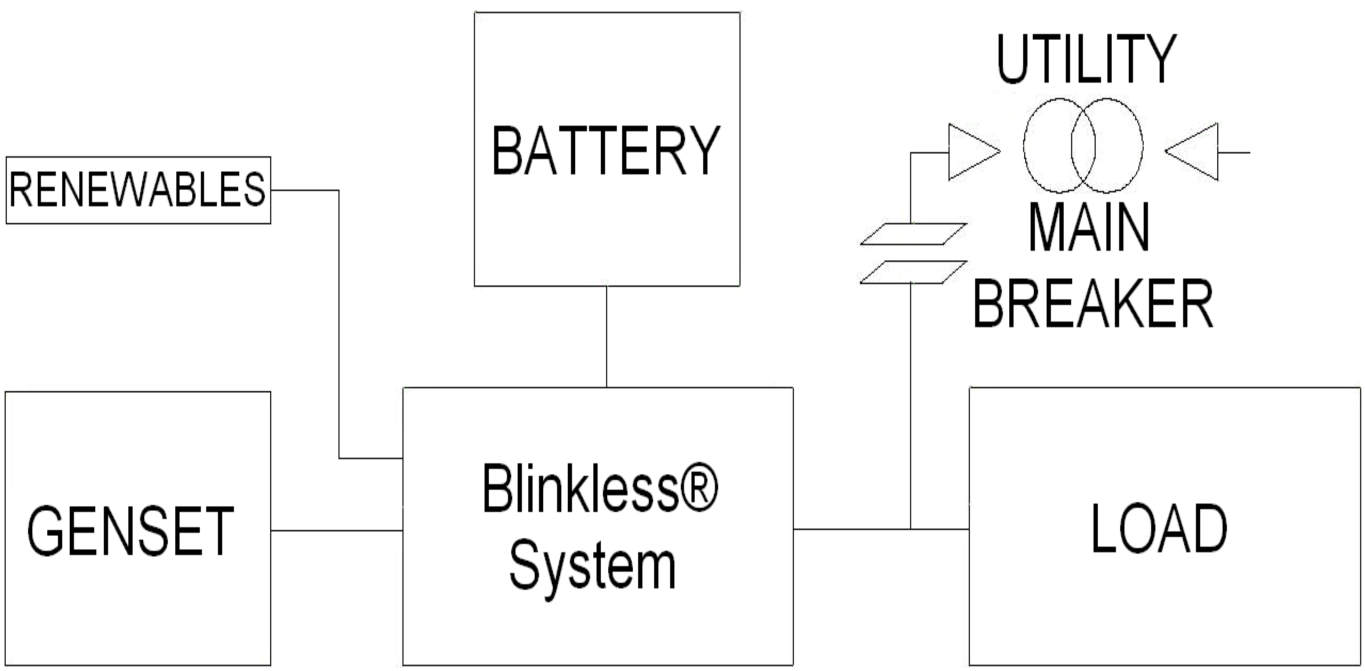
Blinkless® Transfer UPS Style

In the event of grid loss the battery supplies instant energy to the inverter to carry critical loads. If the loss of grid power is long enough to drain battery reserves below a predetermined minimum state of charge the generator starts to supply long term power. The mains breaker would open up in the event of grid loss to ensure safety compliance for utilities. The Blinkless® system is designed to carry any percentage of the connected critical load from 0% to 100%, (150% for short time frames). This type of system can offer full critical load carry with grid loss and grid sync Blinkless® transfer for applications with vital electrical requirements.



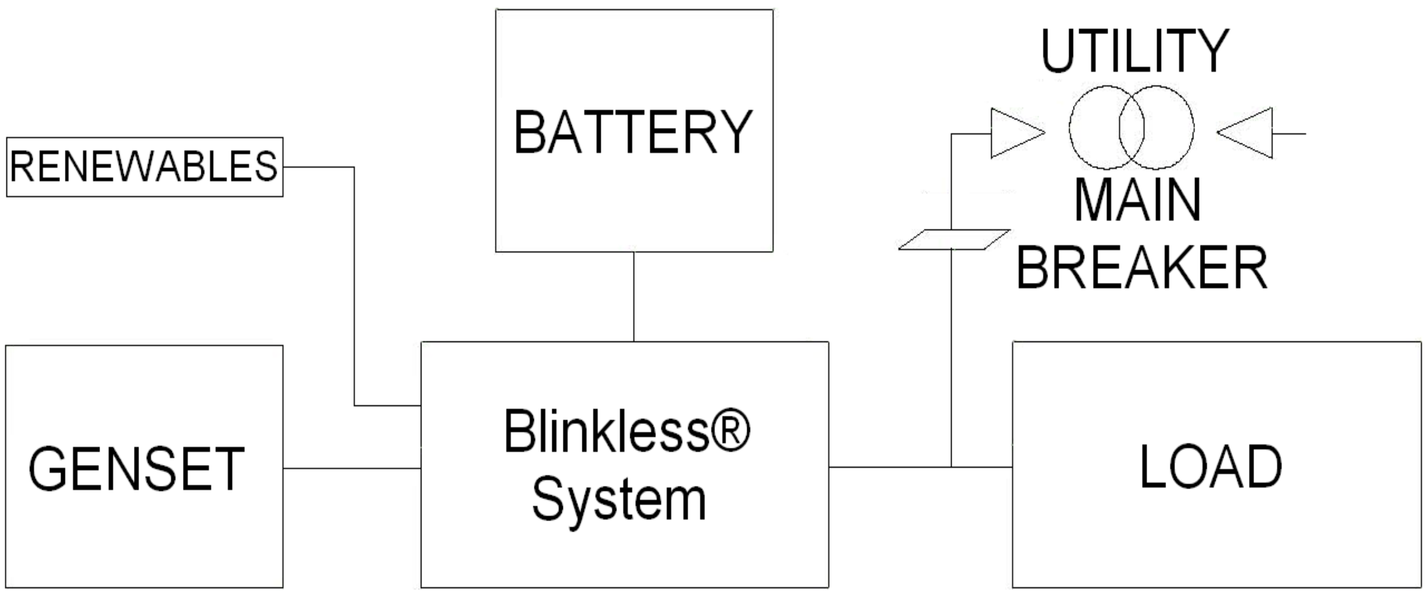
Black Start and Run

The inverter can independently produce a (50) 60Hz fundamental frequency so in the event of a grid loss where the inverter was not already on, it is capable of turning on and running to a pre-set voltage and frequency set point. The energy for starting the system comes from stored energy or a generator. The mains breaker would open in the event of grid loss so that the Blinkless® system could safely start and pick up the critical loads. The system will automatically re-sync and reconnect on grid return.

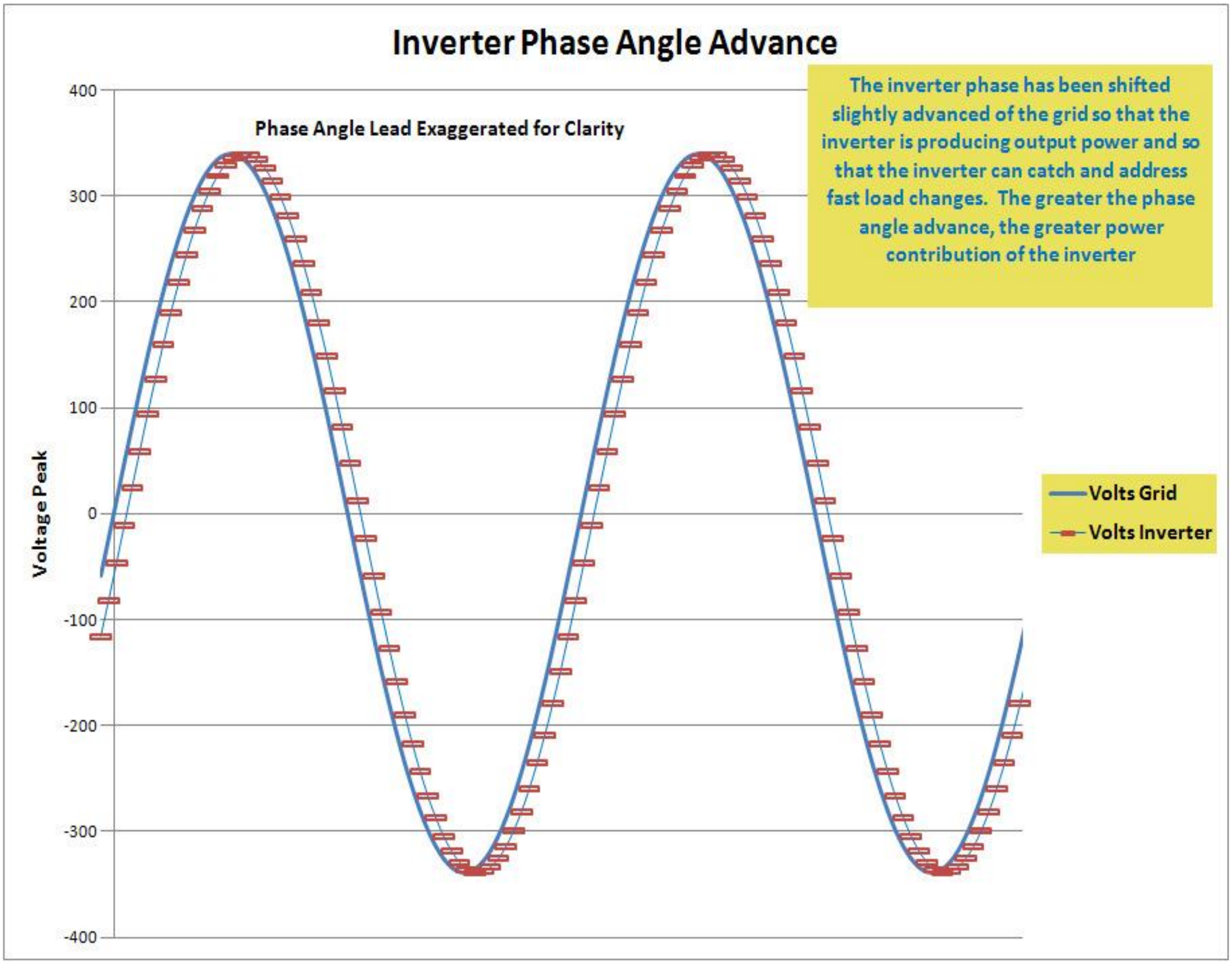


Parallel / Parasitic Peak and Spike Absorption

The inverter can be set to output a small amount of power, thus running in a slight phase angle advance of the grid. When the load draws a large amount of power in a short time, (spike) or an increased amount of power for a longer period of time, (peak), the inverter can buffer the load on the grid using local sources such as a battery pack for spikes and a generator or renewable for peaks. The inverter can also run in 'reverse' in this configuration to charge the battery pack during off peak times. The mains breaker would be closed in this configuration to allow fast pick up of any spikes or peaks.



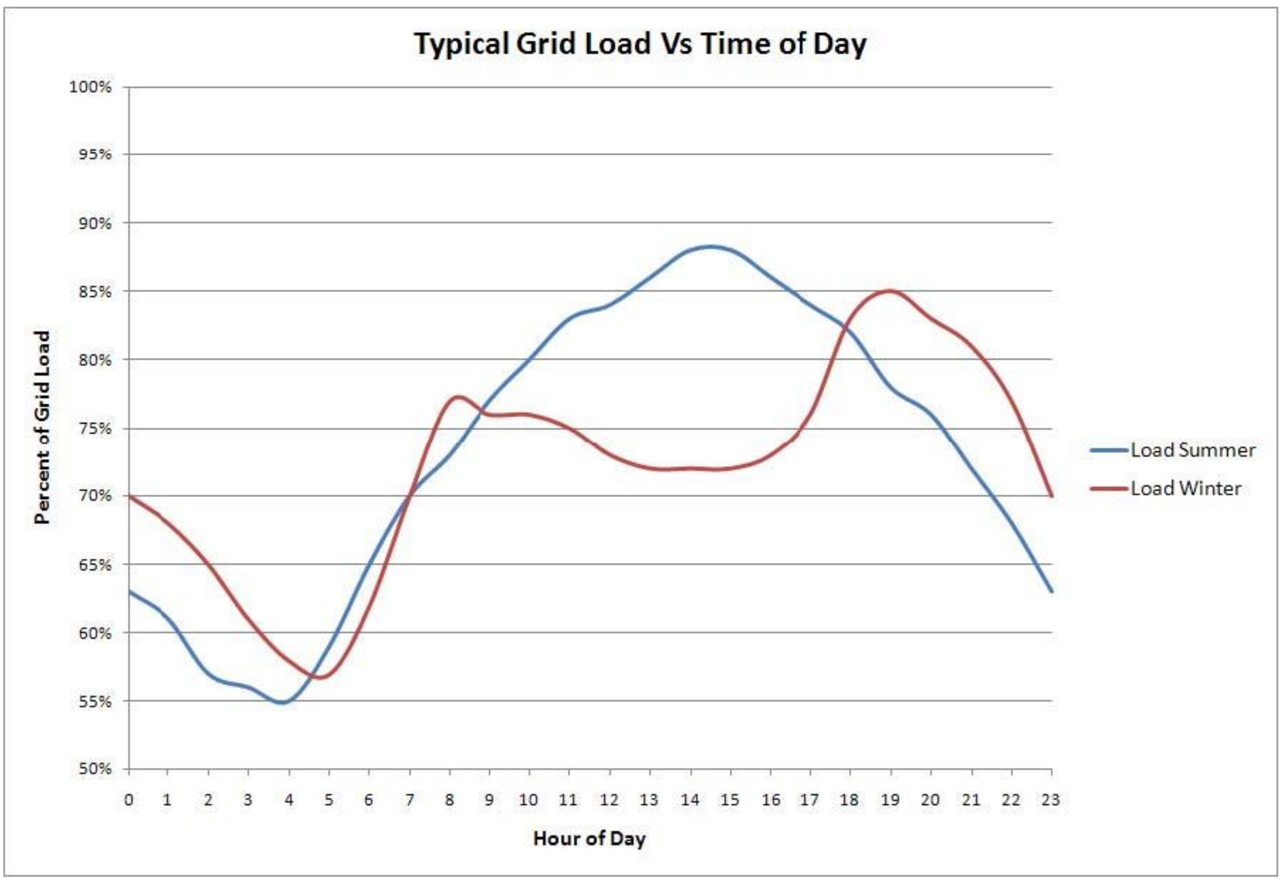
The phase angle advance of the inverter is depicted in the following graph. The advance and subsequent power output can be controlled by a predetermined set point for constant output, or by closed loop control based on a maximum allowable power import from the grid. The phase angle advance parameter can be changed very quickly to ensure that the Blinkless® system contains fast spikes in the system.



Peak Shaving for Point of Use Energy Management Systems

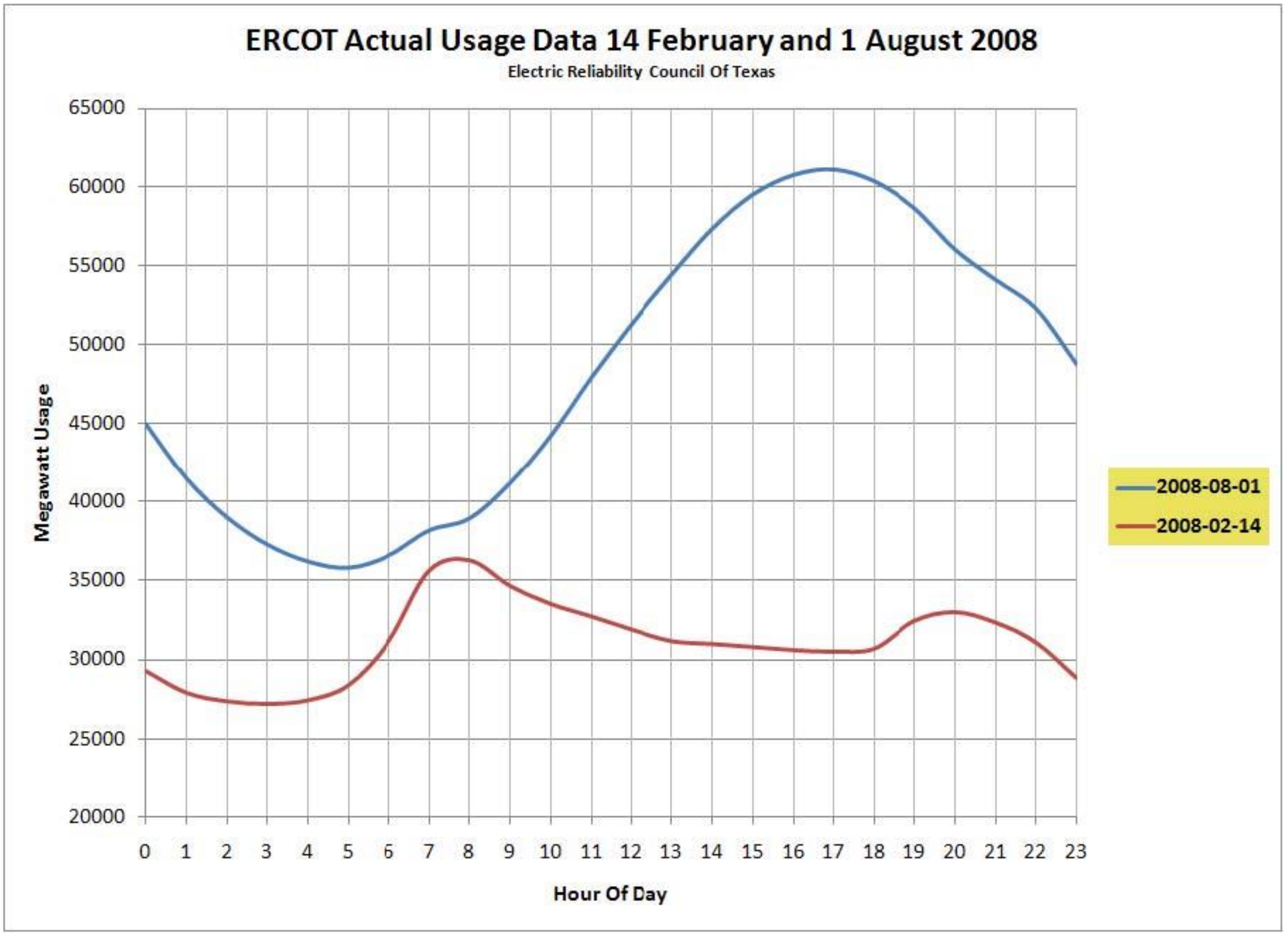
Electrical consumption from a particular utility is not a constant; rather it is a curved function that fits along customer usage profiles. The typical curve is dominated by air conditioning use in the summer months and by lighting and heating in the winter months. The base load, (typical minimum load), can be 50% to 60% of the peak but power plants must be built to handle the peak loads plus a nominal safety factor, or peaker plants must be added to carry maximum loads.

The following graphs demonstrate the usage vs. the hour of day. The first graph is a generalized graph of electrical usage primarily to show the shape of the curves. The second graph is actual electrical usage for the state of Texas on two dates: 14 February and 1 August in 2008, notice that the usage line for February is nearly flat and about 50% of the peak usage in summer. The winter month curve will be different for various parts of the country depending on winter lighting and on electrical usage for heating.



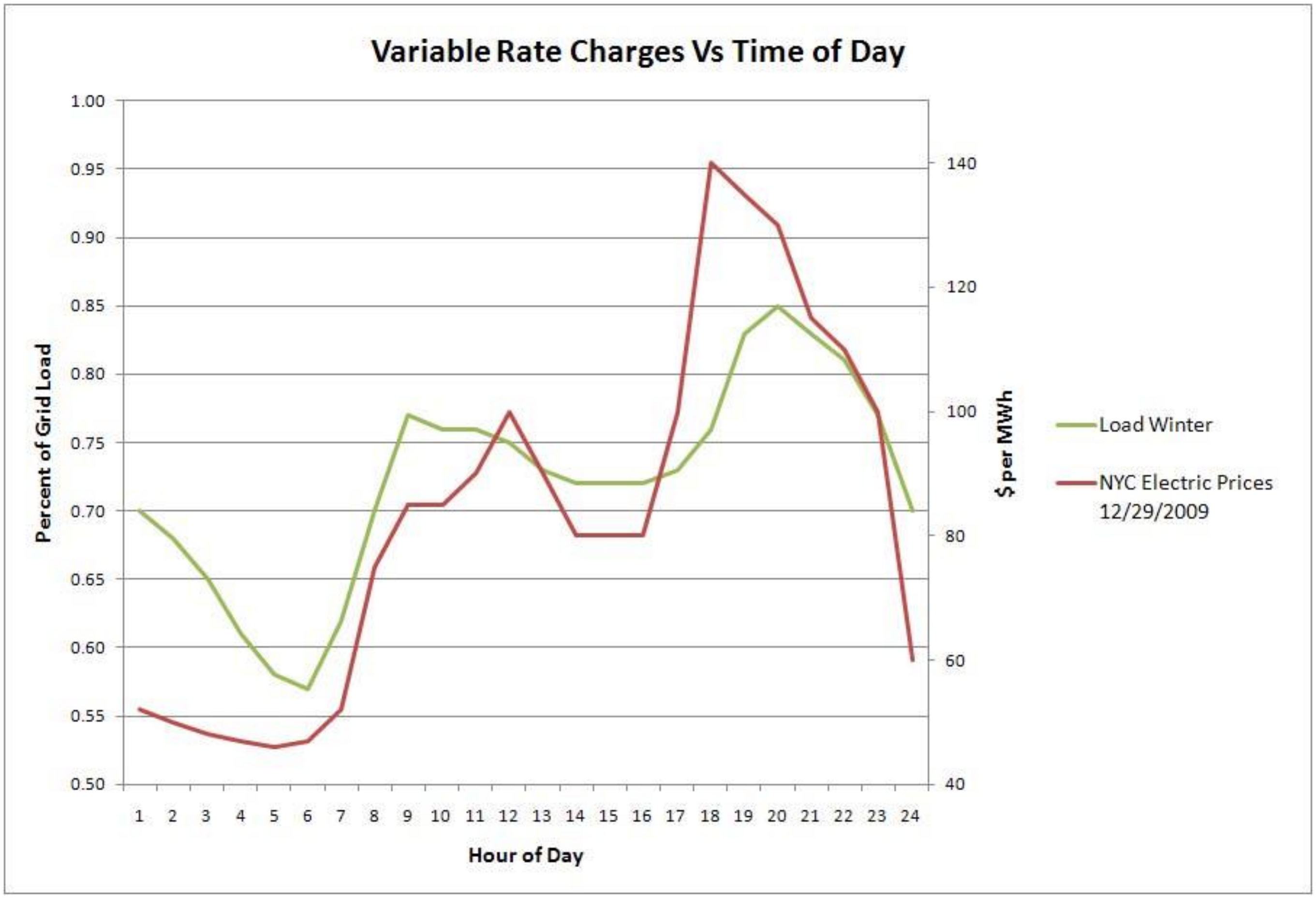
*Graph data is a generalization of typical usage graphs

Usage data for the state of Texas – 2 dates in 2008; notice base usage never falls below 25 Gigawatts for the state and that the usage profile in the summer nearly doubles between 05:00 and 17:00. These large intraday load changes can cause significant scheduling issues for large scale steam driven power plants that may take hours to ramp up in capacity. Usage shifting systems that pull power in the low usage times and provide power in the high usage times at the point of use can be very beneficial to utilities to help smooth out large intraday usage profiles.



• Graph data translated from www.ercot.com – Actual hour by hour usage

Several utilities across the US also utilize variable rate charges based on the time of day, typical peak usage, and local grid congestion to maximize revenue and to encourage time shifted usage to reduce the stress on the local grid.



Graph pricing data translated from www.nyiso.com – Prices are wholesale 12/29/2009
www.eia.doe.gov/fuelelectric.html contains data on usage, pricing and generation

Point of use storage devices provide the opportunity to store energy from off peak time to be used during peak times. The previous chart indicates a price delta of nearly $100 per MWh – ($0.10 per kWh) from the peak rate time at 18:00 to the minimum rate time between 2:00 and 5:00. For instance with the previously stated cost deltas, if 100kWh of electrical energy is shifted it would result in a savings of $10 per day, every day 365 days per year. The pricing of electricity is a variable and is also driven by usage, thus price deltas can significantly exceed the stated example amounts particularly in the summertime when average usage is greater; summertime offsets in cost would generally be greater than wintertime offsets. If the stored energy comes from renewable sources, the savings will be even greater. In addition to cost savings for the end user, on grid storage systems can also be deployed to offset system oscillations and instability for the utility resulting in a more even usage function. The technology can additionally be configured to provide over current capabilities to facilities that occasionally overdraw the available site power. The instantaneous required power is supplied by the system batteries so that the grid does not see a spike and the site circuit breakers do not trip.

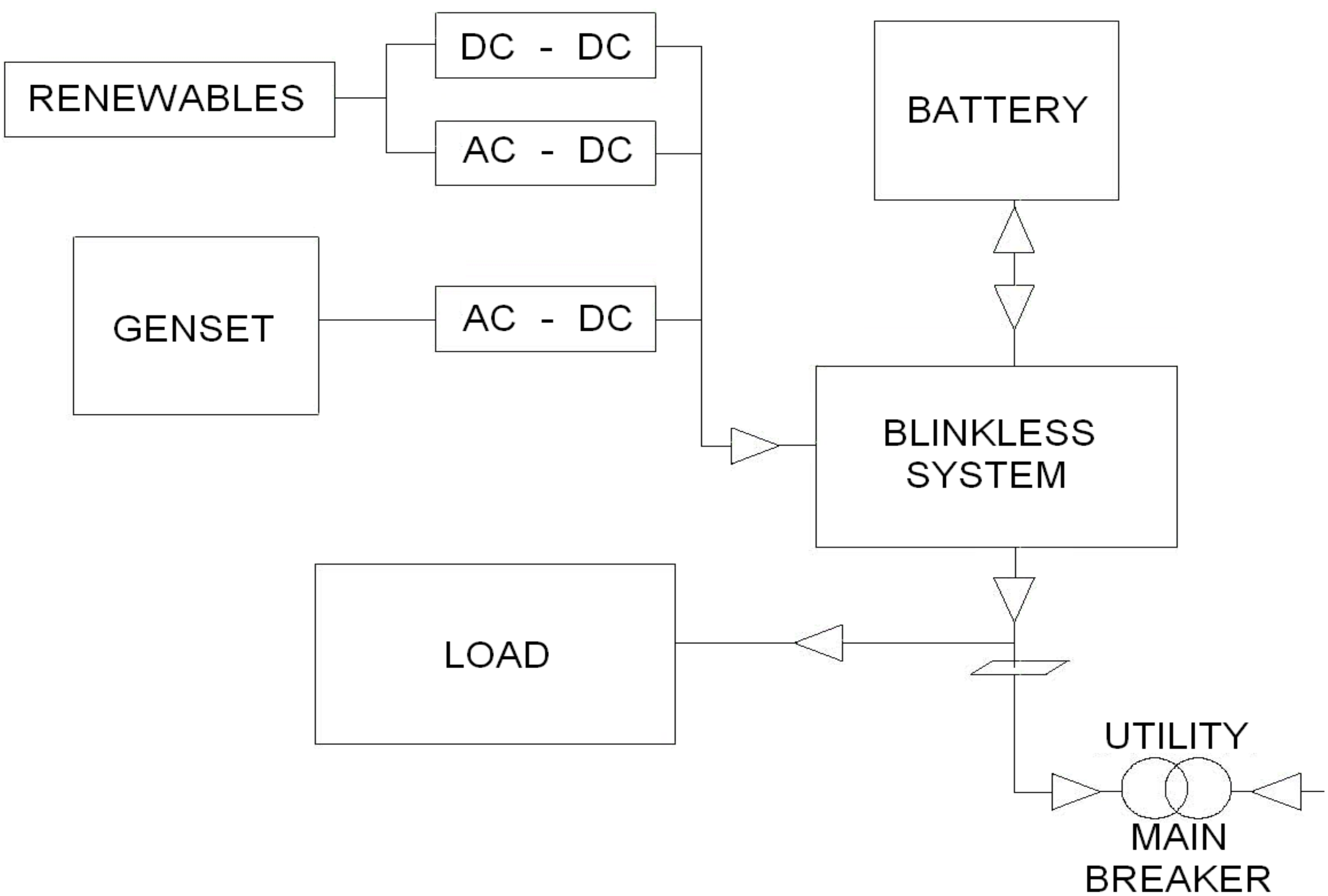
Multiple Input AC-DC / DC-DC Converters and Source Select

Renewable sources typically run without voltage and or frequency control. Solar (PV) systems run with variable DC voltage set points so they may need to be converted, usually increased, to a voltage level compatible with the inverter DC bus nominal voltage. The voltage step up is achieved with a DC – DC converter.

Windmills may run with variable frequency AC voltage that need to be converted to a safe and useable voltage to be compatible with the DC bus; this is achieved with a combination of AC transformers and solid state DC rectifiers to transform AC to the correct voltage DC. Either voltage conversion process may be replicated as many times as required for as many inputs as desired.

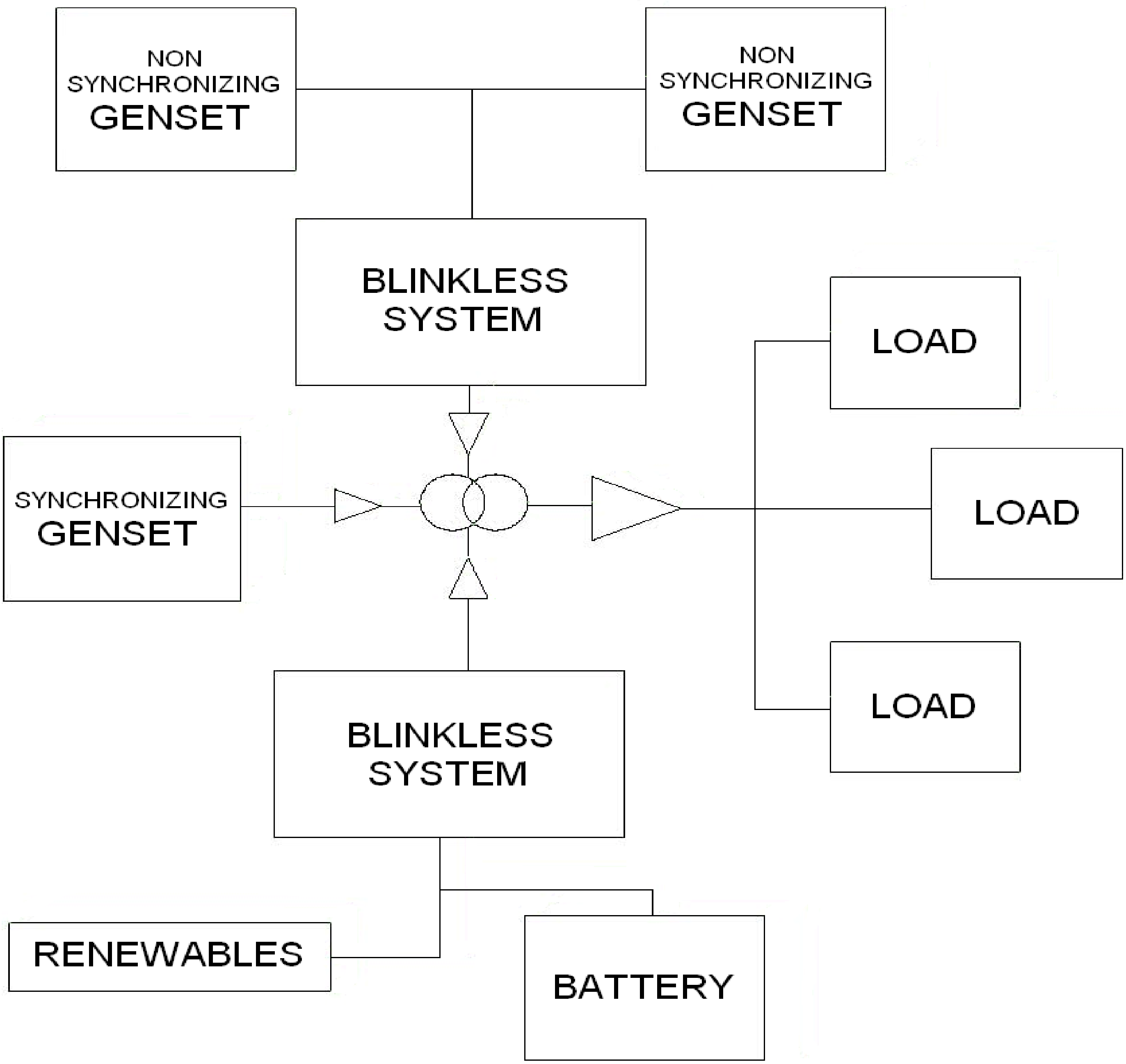
The following system also shows an independent battery charger that allows for continued inverter output while the battery is being charged. The voltage converters may also be tied back into the main inverter control system so that the step up voltage is determined by a selection algorithm to choose the desired source. The source with the highest initial voltage will supply all of the system power until its voltage drops to the level of the next highest source. By controlling the voltage of the input sources, the system can choose which input supplies power first, second, third etc.

Energy add-on's would be site and customer specific to tailor the system to exact specifications and to leverage geographic dependent and/or mandated energy sources. The mains breaker would be closed in this configuration to allow the Blinkless® system to supply renewable power to the grid.



Micro Grid Applications and Setup

The inverter system can run in stand-alone state or in a grid parallel mode, this feature allows the system to form a remote stand-alone micro grid. The inverter can sync to an established voltage and frequency signature, this signature can come from the utility, a generator, or another inverter. In the case of a generator or inverter, the resulting power structure is a micro grid. Micro grids can be very important for forward operating military bases or to areas where the utility is nonexistent or has been damaged. Micro grids allow for the connection of several input sources by syncing the generating devices and sharing load between them. The following example shows a micro grid driven by 2 Blinkless® systems and a synchronous generator. The non-synchronous generators, battery and renewable sources are all synced into the micro grid by the Blinkless® systems.



Blinkless® Summary

Electrical power generation in the US will undergo changes in the coming years. From renewable inputs, distributed generation and smart grid initiatives; the electrical infrastructure will require modifications for multiple inputs and a more efficient delivery of power.

The most common renewable energy sources such as solar and wind require power electronics to mate the uncontrolled power generation to the controlled distribution network, the grid. Typically the interfacing devices provide correct voltage, frequency and phase however they have no provisions or controls for power optimization in terms of grid demand, fluctuations in terms of voltage droop or frequency stability or for renewable generation.

Usually these devices can provide more electricity when the power is available from renewables or other sources but they cannot be ‘flexed’ to truly augment variable grid load demands, counteract large current spikes, or store energy when the local generation exceeds demand or transmission capacity. Transmission capability issues are also tied to grid load; if renewable sources can provide more power than can be transmitted the renewable must be scaled back and the power generation opportunity is lost.

Due to the cost and complexity of the required electronics; increasing the capability of the electronics helps to mitigate the inherent cost. Implementation of strategies such as storage, usage time shifting and peak shaving into the grid interface device can shorten payback timing for initial capital costs. While the specifics or these strategies would vary from user to user, a highly flexible electronics platform could be configured to cover any situation in a real time environment such as load demand that follows the hour of the day as well as the time of year. The inherent unpredictability of renewable sources, particularly wind, does not lend itself to true grid backing and load reduction functions.

The ability to produce energy in a sporadic and unpredictable way but use the energy in a fashion that can supply all the required power at the required time would truly enable the large scale adaptation of renewable energy.

A similar analogy can be made with distributed generation resources and point of use storage and control. Storage systems with power electronics have been available for some time; UPS systems utilize stored energy from the grid to supply critical loads with continuous electrical power in the case of an outage. A parallel UPS style system with enhanced capabilities in both the power electronics and storage systems is the best solution for both distributed energy augmentation and for time shifted usage profiles.

Remote control of local power electronic modules and storage devices by the utility is the basis of the so called ‘smart grid’; single point storage and conditioning of renewable power sources in urban or suburban residential or light commercial areas would spread out the cost and benefit of implementation of alternative energy sources

Sophisticated, highly adaptable power electronics coupled with local generation and storage in distributed generation applications could have profound effects on cyclic grid loading and the ratio between base load and peak load.

The Blinkless® platform has been developed with true energy management in mind. Combining the security and stability of a UPS with the interfacing functions of a renewable grid tie and the re-syncing blink less transfer of a synchronous generator system with fast peak shaving and overload protections; the Blinkless® system is designed to provide shorter capital payback as well as enhanced site capability

Typical Blinkless® Applications

Utility

- Renewable / utility point of use energy storage systems
- Smart Grid communication interface and short term supply
- Utility Peak- trough smoothing with point of use control
- Soft sync connections to fragile grid systems

Industry

- Critical load carry thru UPS with no continuous grid pass thru and loss of efficiency
- Stand by generator complement and sync system with battery carry thru
- Industrial based distributed power generation systems
- On line, parallel / parasitic UPS for fast peak shaving or 'overdrive' up to 150% of nominal power rating for up to 60 seconds
- Full critical load carry with grid loss and grid sync Blinkless® transfer for medical facilities and other operations with vital electrical requirements

Residential

- Individual home based distributed power generation system and peak shavers
- Subdivision based distributed power generation systems and peak shavers
- Multi point renewable energy storage and conditioning

Military / Government

- Micro grid applications for forward operating bases
- Micro grid applications for areas where the local grid has been damaged or destroyed
- Multi point renewable energy storage and conditioning
- Micro grid applications and interconnect from generators or grids with frequencies or voltages that are different than US standard and/or from each other

Definitions

Uncontrolled power generation –Power that is produced with unregulated voltage, frequency or both

Frequency – Number of cycles an AC source completes in a unit of time – i.e. 60 cycles per second = 60Hertz, (Hz)

DC voltage – Direct Current A voltage that is static in time, one wire is positive and one in negative, this is the type of power that a battery provides

AC voltage – Alternating Current A voltage that alternates in time between a positive value and a negative value, this is the type of power that the grid provides

Inverter – Electronic device that converts DC to AC via Power electronics

Distributed Power – Power generation with smaller units over a spread out geographic area as opposed to a large centralized generation plant

Grid Parallel – A condition where add-on power generation produces electrical power concurrent with and attached to the established grid

Grid Isolated -A condition where add-on power generation produces electrical power independently of the established grid; if an established grid even exists

Renewable -A supply of energy that exists naturally and is replenished at a substantial rate. Primary examples are sunlight, wind, tides and biomass

Micro grid – An interconnected electrical distribution system that is several orders of magnitude smaller than a state wide or regional distribution grid – i.e. kilowatts vs. gigawatts

UPS – uninterruptible power supply – a storage and electronics package that provides electricity from on board or on site storage when the main line utility is not present

The Blinkless® inverter system is a patented energy management solution for a variety of applications.

Gary Gengenbach: Blinkless Power Equipment; garyg@mesindy.com