Product catalogue

Nilar reoxygenating series

Pioneering batteries, Battery Management System and reoxygenating technology for stationary energy storage systems. Collaborating with expert energy storage system integrators to optimize energy management.

We develop and manufacture batteries that are part of stationary energy storage systems. With better energy storage, society can support the increasingly stressed electricity grid by bridging imbalances between energy production and demand, especially important as the share of renewable energy sources increases. Nilar's ReOx® battery technology is based on Nickel Metal Hydride (NiMH) electrochemistry with a water-based electrolyte, which provides both higher safety and better performance while allowing the components to be recycled and reused. Nilar has its headquarters in Täby and since 2012 all batteries have been developed and produced in the production facility in Gävle, which is powered by 100% renewable energy. Learn more at www.nilar.com.

Contents

Nilar in brief

Distinct product benefits

Performance

The ruggedness of the Nilar Hydride® chemistry leads to a different ageing process, only wearing when storing and providing energy. Through the patended reoxygenating technology, the number of cycles for each battery can be extended multiple times. The battery is capable of quick charge and discharge, delivering numerous cycles over its long calendar life. The unique combination of the Nilar Hydride® technology and our patented bipolar construction provides a reliable source of power designed to last.

Safety

The water-based electrolyte used in Nilar batteries is nonflammable. Uniform current flow paths lead to no concentrated hot spots and more efficient heat dissipation. The structural components within the battery paired with the nonflammable electrolyte means there is no spontaneous ignition and no uncontrolled heat propagation.

Sustainability

The Nilar R&D process focuses on the Circular Economy philosophy, with every innovation striving towards component renewal and waste reduction. With the Nilar reoxygenating technology, the lifetime for each battery can be extended multiple times, thus each battery can be reused before recycled. All Nilar products are produced at our factory in Sweden with 100% renewable energy and are able to be recycled at end of life. Unlike most industrial batteries, Nilar batteries do not contain, nor need cadmium, mercury or lead and are made with minimal hard-to-recover raw materials.

Applications

Nilar's vision is to enable safe and sustainable energy systems through our pioneering battery technology. Through close collaboration with system integrators, we can optimize energy management for end customers with battery solutions that are sustainable, safe and have high performance.

Safety

Nilar Hydride® batteries are based on a mature technology that has been used commercially for over 25 years for a variety of applications including consumer products, electric vehicles, hybrid electric vehicles, and stationary power applications.

The main safety benefits of Nilar batteries are:

- Battery system with water based, non-flammable electrolyte[1]: No risk of spontaneous fire or explosion.
- No risk of short circuit generation even under low temperature charging as observed in other solutions: No risk of spontaneous release of energy, rapid temperature increase with fire and explosion as potential consequences.
- Electrodes contained in Nilar modules cannot ignite or react spontaneously: No risk of heat propagation between modules under normal operation and rest periods[2].

A significant part of the BMS functionality is to keep the battery from states which may affect reliability and safety. This mainly concerns the prevention of overcharge, over-temperature and short circuits.

But even in the case of BMS failing or malfunction, Nilar batteries show a high degree of passive safety under abusive treatment[3]:

Overcharge: Depending on the charge current, Nilar batteries can manage an overcharge for several minutes to hours without venting. During overcharging with higher current over longer periods of time, the maximum internal pressure may be exceeded, consequently, the safety vent could open, releasing gas.

Over-discharge and reversal:
Over-discharge of modules down to 0 V is not critical for safety since it does not cause a pressure nor a temperature increase. However, it has a negative impact on performance and longevity and should therefore be avoided. Continuous reversal can lead to an internal pressure build-up, activating the safety valves. Any associated temperature increase will be modest and non-critical.

Short circuit: Fuses are an effective protection against external short circuits.

External heat/fire: If an external fire would occur near the battery bank, the fire should be extinguished by CO_2, in the same way as a corresponding electronics fire. If the fire is not extinguished, the heat will eventually cause the Nilar batteries to ventilate. This scenario should be addressed in the same way as a corresponding fire in a lead-acid battery installation.

(1) Electrode materials in Hydride batteries (NiMH) are chemically stable when in contact with the electrolyte. There are no heat generating reactions taking place between the electrode materials and the electrolyte and no solid electrolyte interface is needed to protect the electrolyte from electrode materials. This can be compared to chemistries containing highly flammable organic electrolyte. If the organic electrolyte is catching fire, explosive and poisonous gases are released.

(2) Propagation is a dangerous phenomenon that can occur in batteries based on other chemistries, where one cell that has run into thermal runaway can spread the heat to other cells, in that way initiating thermal runaway in other cells and causing a cascade effect.

(3) Several battery chemistries require a very strict safety region when it comes to upper voltage limits, temperature limits and current limits. If you pass the set limits you enter the safety critical region where thermal runaway can be triggered by internal short circuits and/or external heat. For example, during deep discharge or overcharge.

Certified for Transportation by Road, Rail, Sea, or Air

One of the advantages with Nilar battery packs, as compared with many other battery types, is that UN approved packaging and marking is not required for transport by sea, road, rail and air. No dangerous goods documentation is required when transporting Nilar battery packs by road or rail. Nilar batteries are also certified for transport via road, rail, sea or air, without the need for heavy and expensive explosion-proof containers.

A dangerous goods declaration is required if batteries are transported by sea in quantities of over 100 kg in one transport unit. Nilar battery packs are then defined as dangerous goods, class 9. UN number and Proper Shipping Name are UN 3496 and Batteries, Nickel-Metal Hydride respectively.

Transportation of Nilar systems is easy to manage, since the IMDG Code provisions do not apply on Hydride batteries (NiMH) contained in or packed with equipment, according to Special Provision 963.

An Air Waybill or similar is required if batteries are transported by air. Nilar battery packs are not classified as dangerous goods and belong to the entry "Batteries, dry" in the list of dangerous goods in IATA (no UN number). If an Air Waybill is used, the words "Not Restricted" and the Special Provision number (A123) must be included in the description of the substance on the Air Waybill, according to IATA-DGR.

For several other battery chemistries, heavy regulations apply for all modes of transport, especially regarding transport by air. For those classified as fully regulated dangerous goods, strict regulations and even training courses may be required for the personnel involved in the transportation.

Standards:

- Transport UN38.3 Test T1 Altitude & Test T3 Vibration
- Transport ADR-S SP238 Test A

Sustainability

Contributing to a circular economy is part of everything we do, from design to completion and recycling of batteries. All products that leave our production plants must meet our high standards. The flat cell construction of our batteries is designed to simplify disassembly. This allows materials to be reused and recycled. Nilar's batteries are the sustainable choice.

Sustainable design for increased service life and lower life cycle cost

Manufacturing and recycling of batteries is resource intensive. Furthermore, most batteries have major limitations on their service life. Nilar is first in the world with a technology that enables spent batteries to be restored and given a new service life. The technology is called ReOx® and it enables batteries to be replenished with new oxygen before they are worn out, extending the battery's service life by at least three times. There are numerous benefits, the battery's performance is retained for longer, at the same time as the circular life cycle is beneficial for both the environment and the users' wallet. With ReOx®, Nilar is building a reliable and safe source of power designed to last for a long time. Our battery management system (BMS), software and sensors that ensure that the battery is used as efficiently and safely as possible are also important for the service life.

Choice of material and design increases the battery's performance and safety

Nickel, the central component, is a raw material that is accessible, fire-proof and recyclable. Nickel-based chemistries function well within a wide temperature range. This is an advantage compared with other battery chemistries that are flammable and that furthermore emit toxic gases in connection with a fire. Thanks to unique solutions within design and integration, our products have a high safety performance. The electrodes cannot ignite spontaneously. Every fire close to a Nilar battery can be treated in the same way as any other electrical fire and extinguished with a carbon dioxide extinguisher. There is no risk of explosion or severe uncontrolled fire in Nilar's battery chemistry. The bipolar design is the key to efficiency in relation to materials and space. The flat battery modules are stacked serially, with few intermediate connectors, resulting in a uniform flow of current across the cells, reducing electrical resistance and optimising performance. The modular design facilitates simple installation.

Recyclable product

The circular concept permeates everything we do, from design to production. The battery cells' flat design is formulated in order to simplify reuse and recycling, where material can be used in new batteries. The constituent raw material, nickel, is easy to recycle. When Nilar batteries that have been in operation are worn out, they are returned to Nilar for reuse and processing prior to recycling of the constituent material. As a part of our sustainability efforts, we are developing processes so that we can maximise the proportion of material that can be reused for new Nilar batteries in the future.

Nilar's batteries from a life cycle perspective

We have conducted a life cycle analysis in order to gain a better understanding of how our Nickel Metal Hydride batteries affect our environment, as well as to identify areas where we can become better. The analysis has been conducted in collaboration with Triathlon Greentech. As far as possible, underlying data has been obtained from Nilar, along with supplementary data from transparent sources and databases that are considered relevant based on temporal- and geographic aspects.

Efficient and environmentally friendly production

To minimise the environmental impact from the production process, 100% renewable energy is used throughout the production plant in Gävle. All our testing equipment for mass production that is used for charging and discharging of our batteries has functions that enable current to be reused or sent back to the electricity grid. The production process benefits from automated efficiency, which ensures that it is as resource efficient and environmentally friendly as possible. There is currently a certain amount of material waste in our production of electrodes. Material waste is currently sent to external partners for recycling, but the aim is to return this material to the production process. Method development has taken place together with Uppsala University and ReSiTec, with tests of the method now underway in our production.

Continuous Innovation

Nilar's research and development processes place a major focus on circularity. There has been significant investment in research into direct recycling strategies to advance the sustainability of the production process. The batteries' software is under continuous development in order to

increase efficiency and functionality. Furthermore, our research into extending the service life makes it possible for batteries to go on after their conventional end date, leading to a long-lasting solution.

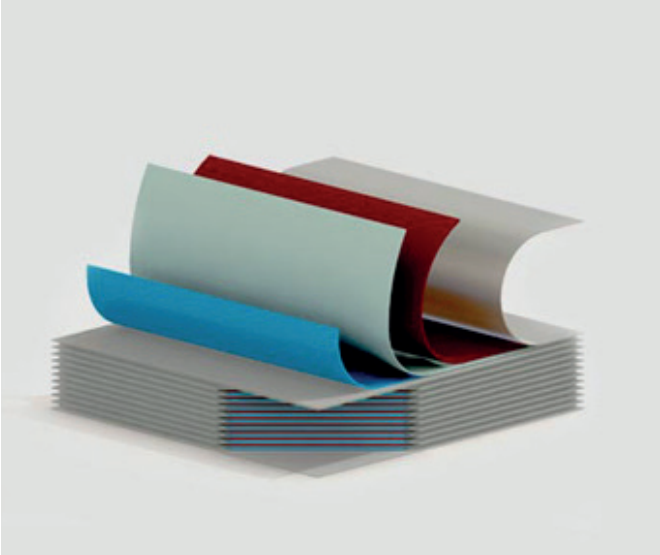
International supply chain

Nilar buys raw materials from all over the world, where most of the large suppliers are within Europe and Asia. As new suppliers are onboarded, they are required to work according to ISO 9001, ISO 14001 and ISO 45001/OHSAS 18001. Nilar has started the work of evaluating the current supplier base according to a formal auditing process, in order to ensure that we maintain a desired level of quality in our supply chain. The audit process functions as a countermeasure to the risks associated with environmental and social issues.

Nilar products are compliant with the following directives and regulations:

- EU-directive 2006/66/EG ('Battery Directive'). The batteries do not contain the heavy metals mercury or cadmium.
- Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU
- Restrictions of certain hazardous substances according to RoHS Directive 2011/65/EU.
- Nilar products are in compliance with Regulation (EC) No. 1907/2006 concerning the Registration, Evaluation, Authorization and the Restriction of Chemicals (REACH).

Performance



One of the superior features of Nilar batteries is the very stable performance over life. Typically, the impedance of a battery increases when the battery is used. This results in reduced run time and finally, depending on how end of life is defined, the battery is not able to perform as required. The stable and well defined performance over life experienced with Nilar batteries is a consequence of the intrinsic features of the Nilar Hydride® technology together with the high manufacturing quality gained by the Nilar patented bi-polar design. The main ageing mechanism is dry-out, causing a slow increase in impedance over cycles.

Long life and robust design

The robust Nilar Hydride® chemistry combined with our patented bipolar construction, contributes to the long service life of the battery. This provides a reliable source of power designed to last. Uniform current and resistance paths promote uniform heat generation, which enables uniform ageing of the cells and ensures longer cell life. The volumetric overhead, being approximately zero in comparison with other battery designs, combined with the large current collectors make the design ideal for high discharge rate applications.

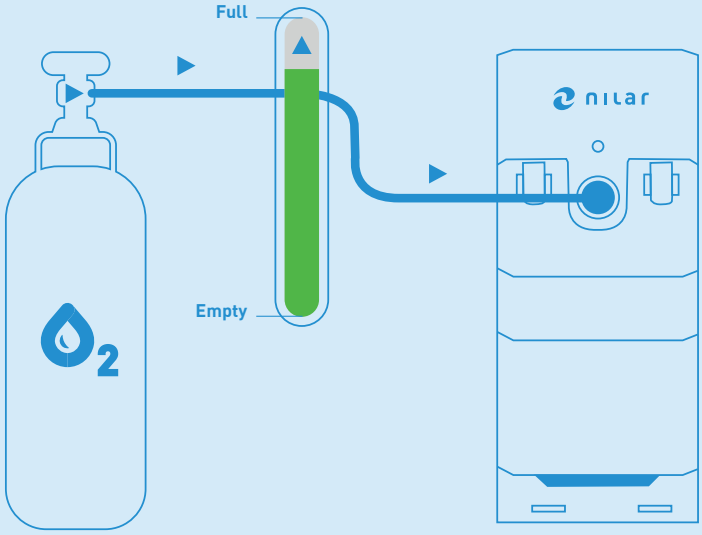
Sophisticated Battery Management System

The Nilar Battery Management System (BMS) monitors, controls and protects batteries to maintain a long service life. The fine-tuned management system optimizes battery operation for best-in-class reliability, safety and efficiency at all time.

Extended lifetime with ReOx®

Our patented ReOx® technology balances the electrodes and replenishes the electrolyte by adding a controlled amount of oxygen. This process brings your Nilar Hydride® battery back to its initial 100% capacity, extending its useful life by more than three times. The reoxygenation functionality is built on thorough scientific research and extensive experimental analysis. Starting at Stockholm University, there was an exploration of the reversibility of chemical side reactions. The side reactions cause corrosion of the metal hydride component, but more importantly, consume the water within the electrolyte. This electrolyte depletion leads to the main source of failure within a nickel metal hydride battery: dry out. Because Nilar Hydride® batteries utilize gas recombination reactions, a controlled introduction of gas can regenerate the water-based electrolyte.

The groundbreaking Nilar reoxygenating process allows the reconditioning of battery cells multiple times.

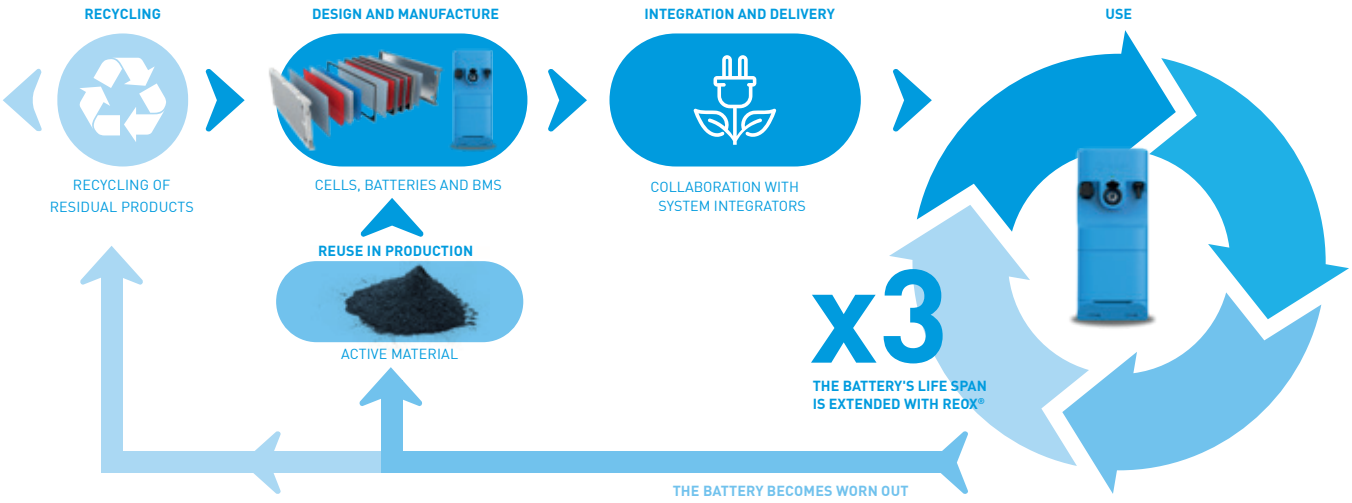


With pure oxygen, Nilar can recondition the battery and reverse its ageing process, thus regaining lost capacity.

Using the reoxygenating technology, Nilar's batteries can be used over and over again, which is both **cost efficient** and **good for the environment**.

Battery production driven by innovation

Nilar is a unique manufacturer of safe battery technology with the focus on designing, developing and producing batteries, Battery Management Systems (BMS) and the life extending ReOx® technology for stationary energy storage systems. Thanks to cutting edge expertise within battery chemistry, production technology, product development and system development, our R&D initiatives have contributed to groundbreaking innovations within Swedish battery research such as the ReOx® technology. Our continual work on innovations has a crucial role for Nilar's continued product development to meet future requirements. We currently have 77 patents registered throughout the world for our unique ways of designing, manufacturing and maintaining batteries.



Market segments

The ideal battery for the home

We think that home owners and residents in apartment blocks should be able to sleep soundly at night knowing that they have safe and environmentally compatible batteries. Thanks to its water-based electrolyte, a Nilar battery cannot catch fire or explode. With substantial benefits within sustainability and safety, Nilar batteries are the ultimate choice for all homes that want to utilise safer and cheaper electricity.

CUSTOMER BENEFIT

- Peak shaving
- Tariff control
- Phase balancing
- Time shifting
- Off-grid

Batteries for commercial & industrial properties

When you choose batteries for a housing association or office property, a shopping centre or a charging station, it is important to minimise risks. Nilar's batteries are the safe alternative for storing energy. Thanks to its water-based electrolyte, a Nilar battery cannot catch fire or explode. The modular Nilar battery supports scalable solutions for energy storage in order to meet the needs within different types of applications.

CUSTOMER BENEFIT

- Peak shaving
- Tariff control
- Phase balancing
- Time shifting
- Off-grid

Long-term power for smart electricity grid & infrastructure projects

Today's electricity grid cannot handle the new requirements from mass charging of electric vehicles and generally increased electrification. Energy storage will be an important part of the electrical infrastructure of the future. Energy storage solutions with batteries from Nilar are an effective way to tackle these challenges.

CUSTOMER BENEFIT

- Peak shaving of renewable energy
- Increased transmission capacity
- Increased utilisation
- Voltage regulation
- Frequency regulation
- Disturbance reserve

A close collaboration with system integrators means that we can optimise energy management for end customers with battery solutions that are sustainable and safe.

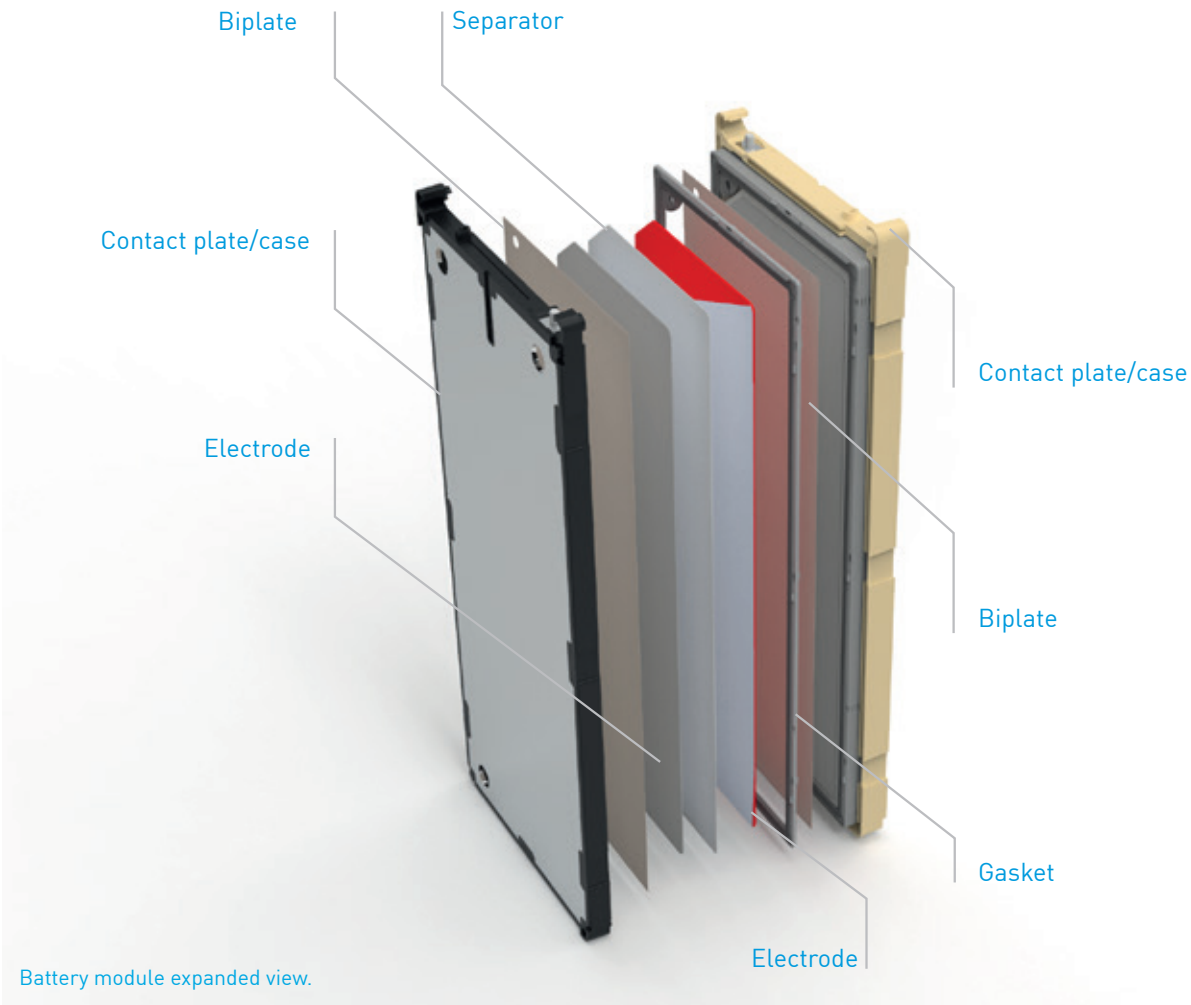
Nilar reoxygenating battery module

The 12 V Module is the building block of Nilar battery packs. As a building block, it provides excellent flexibility in battery pack voltage together with easy sizing towards different requirements and monitoring for battery management. The patented Nilar bipolar cell design and electrode technology allows for a high quality and fully automated manufacturing process. The design is comprised of several patented and unique solutions developed by Nilar. The Nilar inventions cover important areas regarding environment, safety, product quality, life and cost. The 12 V module is sealed and contains no screws.

This also contributes to the easy assembling and disassembling. The outer contact plates acts as current collectors for all cells in the module, thus reducing the volumetric overhead and inherently results in a uniform current flow across the cell. As a result of this, the bipolar design has great advantages compared to the cylindrical and prismatic technologies in terms of volumetric overhead. The uniform current and resistance paths promote uniform heat generation, which enables even ageing of the cells and ensures longer cell life.

Bipolar design with uniform current flow

The unique and patented Nilar Hydride® battery is based on a bipolar design, where cells are laid horizontally and stacked on top of one another to gain maximum space efficiency.



Battery module expanded view.

Battery module design

Electrodes
The positive and negative electrodes are manufactured by a patented method for compression of dry powders without any expensive plate support material, binders or volatile organic solvents. Active materials and additives, as dry powders, are mixed with each other before being compressed in a calendar system to form continuous sheets of compressed electrode material. The sheets of active materials are cut into electrode plates.
The electrode manufacturing process produces electrodes with very high accuracy on dimensions, weight and capacity, contributing to the high quality of Nilar battery packs.

Separator
The separator prevents electrical contact between the positive and negative electrodes in the cell while holding the electrolyte necessary for ionic transport. The superior conductivity and safety of the water-based electrolyte used in the cells allows for the separator to act as an electrolyte reservoir. The high conductivity of the electrolyte also allows for a relatively thick separator, effectively preventing short circuits from any potential defects in the separator or foreign particles.

Electrolyte
The electrolyte in the cell provides means for ionic conductivity in the cell. The water-based electrolyte has important intrinsic features like low cost, fast filling time and excellent ionic conductivity over a wide temperature range. The electrolyte also possesses attractive safety features such as non-combustibility and energy-absorbing capability.

The electrolyte is a solution of potassium hydroxide. The design is a so-called starved electrolyte design with little free volume of electrolyte in the cells. All of the electrolyte volume is absorbed by the positive and negative electrodes and the separator.

Electrochemistry
The Nilar advanced bipolar Nickel Metal Hydride (NiMH) battery module consists of ten cells in series. Each cell contains two electrodes (a positive and a negative), electrolyte, and a separator in-between the two electrodes. The table below describes the compounds in the cell that are active during charge and discharge of the cell. The electrolyte is involved in the chemical reactions at the electrode surface together with the active material during charge and discharge, but is not consumed by the reactions. The strength of the electrolyte is not changed during any of these modes.

Biplate
The biplates, together with the gaskets, are means for sealing each cell. The biplates also provide electrical contact between cells. In the Nilar bipolar design the current is perpendicular to the electrode and bi-plate surface, making the whole biplate area used for current transfer between cells. This substantially reduces resistance and optimizes uniformity of current distribution over the biplate and electrode surface. This biplate design is part of the Nilar patent portfolio.

Gasket
Each cell is surrounded by a gasket. The gasket together with the biplates provide a seal between the interior of the cell and the exterior. The hydrophobic properties of the gasket prevent the creation of electrolyte bridges between adjacent cells.

Case
The case is part of the sealing of the module together with the contact plate. The case is extruded onto the sides of the contact plate. The two case/contact plate units on each side of the 10 cell stack are connected by laser welding, forming a sealed 12 V module. Fittings in the case also make sure that all 12 V Modules are aligned when assembled into battery packs.

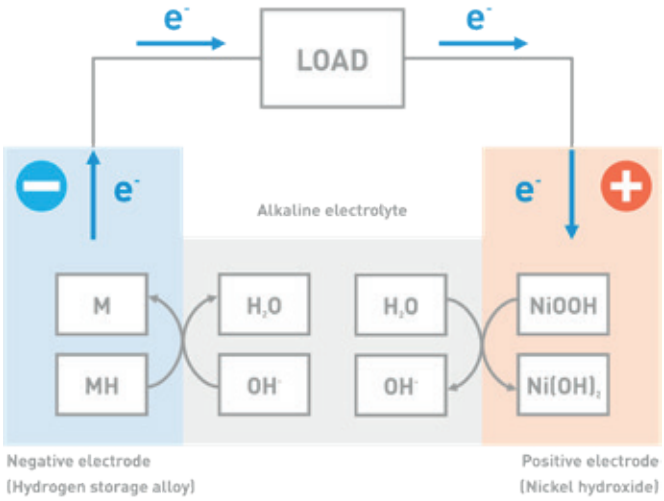
Contact plate
The contact plate is the positive and negative terminal on the module and is also a part of the module enclosure. The contact plate is made of aluminum. Besides transferring electrical current, the contact plate also serves as a heat conductor moving heat from the cells to the long sides of the 12 V Module. This solution is patented by Nilar and enables efficient and low-cost air cooling of battery packs.

Electrochemistry

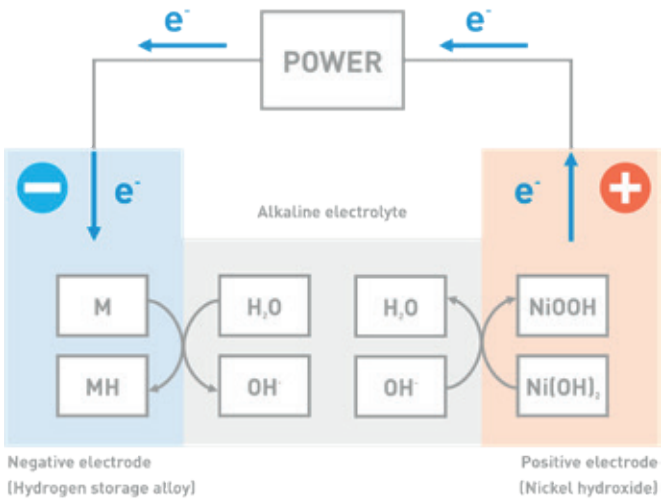
The Nilar advanced bipolar Nickel Metal Hydride (NiMH) battery module consists of ten cells in series. Each cell contains two electrodes (a positive and a negative), electrolyte, and a separator in-between the two electrodes. The table below describes the compounds in the cell that are active during charge and discharge of the cell. The electrolyte is involved in the chemical reactions at the electrode surface together with the active material during charge and discharge, but is not consumed by the reactions. The strength of the electrolyte is not changed during any of these modes.

	Charge products	Discharge products
Positive material	Nickel (III) oxyhydroxide (NiOOH)	Nickel (II) hydroxide ($Ni(OH)_2$)
Negative material	Metal hydride (MH)	Metal alloy (M)
Electrolyte	KOH	KOH

Discharge
When a NiMH battery is discharged, hydrogen moves from the negative active material (MH) to the positive active material (NiOOH). In this process, the metal hydride (MH) is drained of hydrogen and the positive active material is reduced to Nickel hydroxide ($Ni(OH)_2$).



Electrochemical reaction during discharge.



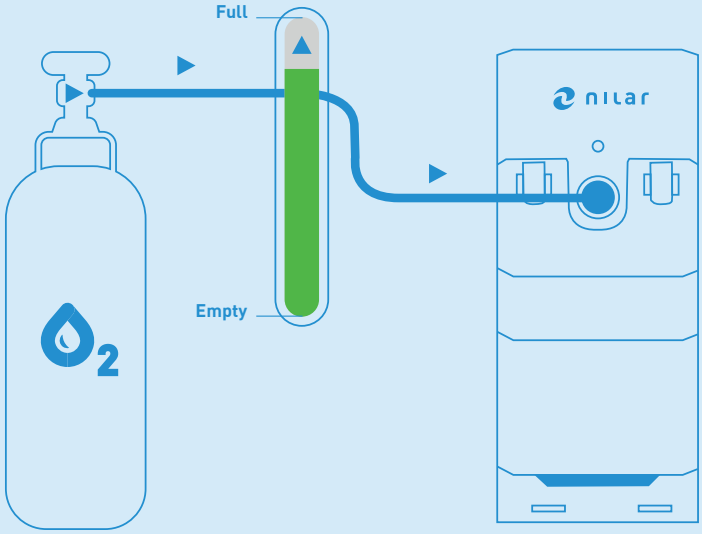
Electrochemical reaction during charge.

Charge
During charge, the hydrogen moves in the opposite direction as compared to the discharge. As the battery is charged, Nickel hydroxide ($Ni(OH)_2$) in the positive electrode loses hydrogen and the metal alloy (M) takes up hydrogen to form a metal hydride (MH). When losing hydrogen, the Nickel hydroxide ($Ni(OH)_2$) oxidizes and the positive active material becomes Nickel oxyhydroxide (NiOOH).

Reoxygenating technology

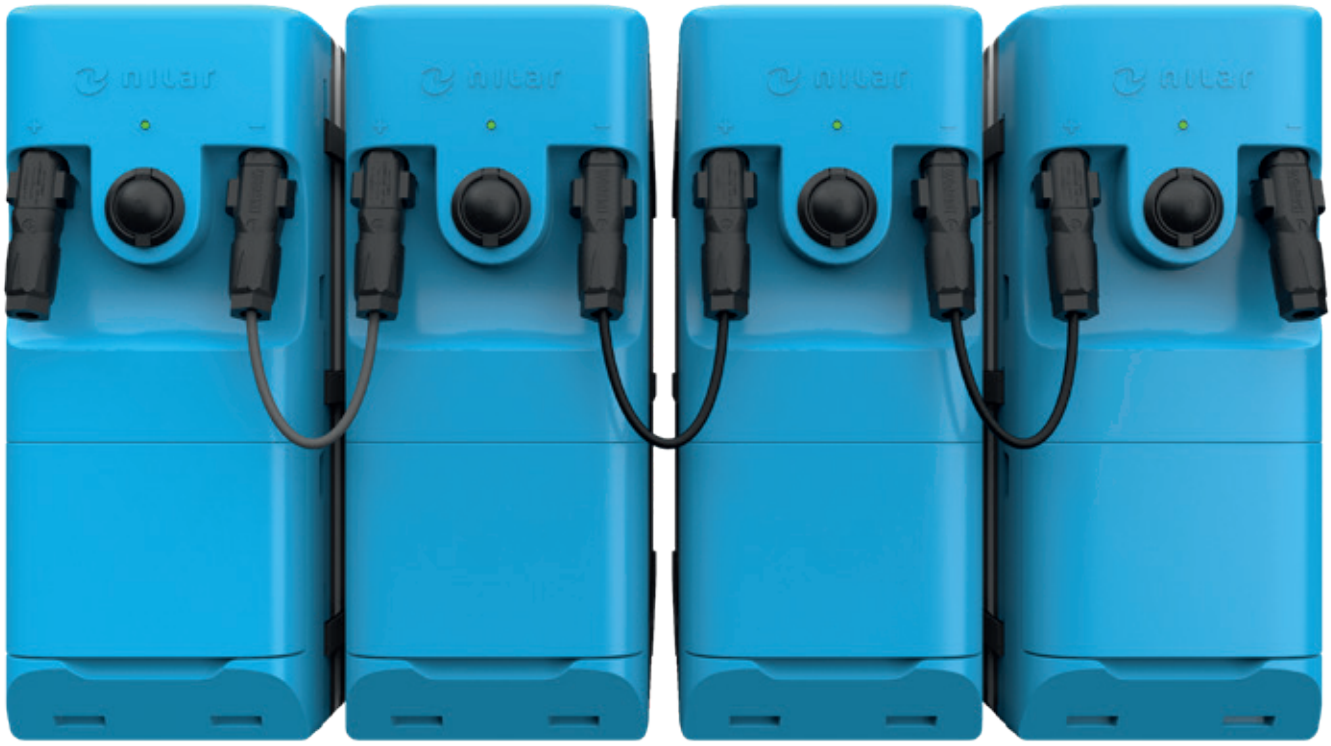
Cell breakdown and ageing of Nickel Metal Hydride batteries is due to corrosion of metal hydride. Corrosion reduces the quantity of metal hydride capacity and uses up the water in the electrolyte, which is bound chemically. The corrosion also produces hydrogen, which increases the internal resistance as a result of an imbalance between the electrodes. Nilar has developed and patented a technique that can balance the electrodes and resplenish the electrolyte by adding a controlled quantity of oxygen and replenishing water in the electrolyte. The technique makes it possible for Nilar to restore lost capacity in a Nilar Hydride® battery, which ultimately extends its useful lifespan more than threefold.

Globally unique patented technology balances the electrodes and refills the electrolyte through a controlled addition of oxygen.

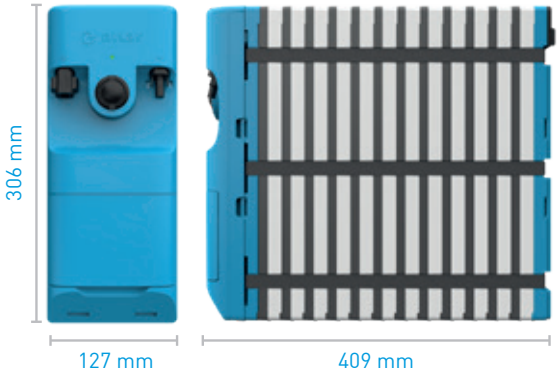


Nilar ReOx® batteries

The sustainable choice



Nilar batteries are made with circularity in mind, from design to completion and recycling of batteries. Our batteries are not only rechargeable, they can also be revived to full capacity at least 3 times through the Nilar patented ReOx® process. This brings savings to your wallet, but above all, makes it easy for you to do the right thing for our planet. Add to that the safety and performance features, allowing the batteries to be installed safely and easily in properties, whether it be a home, office building or industrial property.



Measurement illustration with length including Integrated Monitoring Unit for 1,60 kWh Nilar ReOx® 2 battery pack.

Battery pack features

Nominal voltage
The cell voltage of a battery cell is governed by the electrochemical potentials of the active materials used in the negative and positive electrodes and the electrolyte. For the hydride system used in Nilar battery packs, the nominal cell voltage is 1.2 V. The Nilar 12 V module is comprised of 10 cells connected in series within the module, achieving a nominal module voltage of 12 V. The nominal voltage of Nilar battery packs is determined by the number of 12 V modules connected in series within the battery pack. Battery packs are connected in series to match the required system voltage, forming a string. The nominal voltage of a string equals the number of battery packs multiplied by the nominal battery pack voltage.

Rated capacity
The battery capacity is rated in ampere-hours (Ah) and denotes the quantity of electricity a fully charged battery can deliver at a 5 h discharge to 1 V per cell at +20°C. Nilar battery packs are made with a number of 12 V modules connected in series to achieve the battery pack capacity of 10 Ah. To meet the required capacity of a Nilar battery installation, the battery packs, or battery strings, are connected in parallel. The total battery capacity is given in multiples of 10 Ah.

Operating voltage
Typical cell operational voltage is minimum 1,1 V per cell at discharge to maximum 1,6 V during charge. This corresponds to a 11 - 16 V range for the module.

Operating temperatures
For optimal performance the recommended battery room temperature is +20°C.

Intermediate state-of-charge
Batteries can be stored or operated at an intermediate state-of-charge (SOC) without loss of performance.

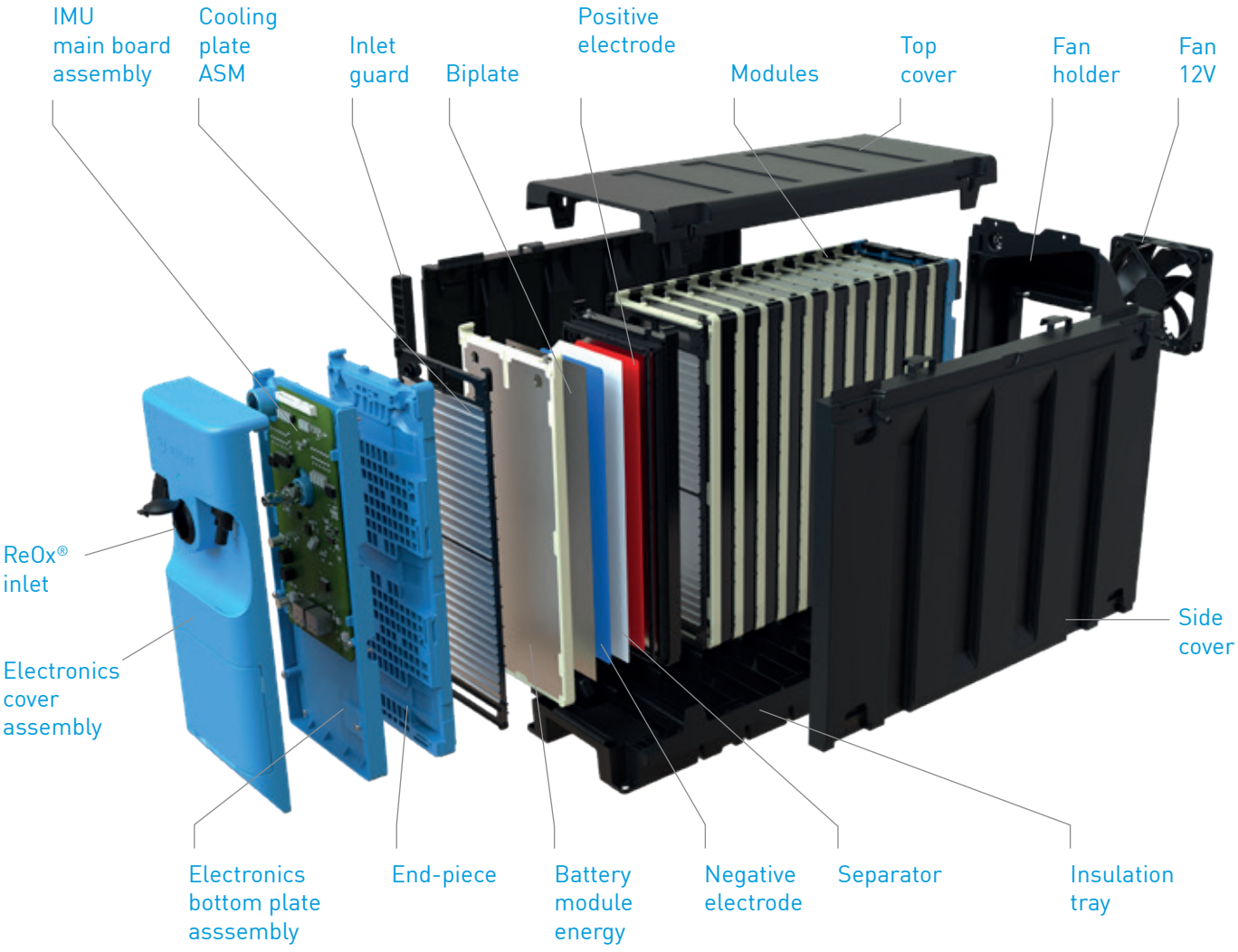
Reliability
The Nilar battery is a stable electrochemical system. The design mitigates corrosion to prevent premature and unpredictable end of life. The design is practically shock and vibration resistant. Testing shows a graceful decline in performance over the life of the pack.

Front view of Nilar ReOx® battery pack.

Nilar Battery Design

The bipolar design enables Nilar to produce modular batteries with improved volumetric power density and simplified battery construction. The main advantage of the bipolar design utilized by Nilar is the common and shared large area current collector. This important feature reduces the volumetric overhead and inherently results in uniform current flow across the cell. Uniform current and resistance paths promote uniform heat gradients over the electrodes. A uniform battery temperature promotes a uniform electrochemical aging of the electrodes in the modules, which translates into a long service life.

Nilar battery packs are optimized for installation in energy storage systems, whether it be for a home, business or infrastructure projects. An Integrated Monitoring Unit is integrated on the battery packs together with industrial connectors for electrical and communication interfaces. The electronic battery pack system, communication bus and the battery packs are designed to fulfill requirements for electrical safety in battery systems with a nominal voltage up to 600V.



Expanded view of Nilar ReOx® battery block.

Pack design

The pack designs achieves a compact assembly of cells and other components required in a battery pack to meet required system voltage and run-time. They are assembled into a pack by a pick-and-place manufacturing process, followed by electrolyte filling and formation using a few charge/discharge cycles to activate the electrochemical system in the cells.

End-piece
There is one end-piece on each side of the battery packs. Together, with the steel bands, the end-pieces provide uniform cell compression over the electrode surfaces, impact protection to the cell stack, and electrical insulation from the pack potential.

The end-pieces also serve as a support structure for the Integrated Monitoring Unit mounted on one of the end-pieces of the battery packs.

Integrated Monitoring Unit
The Integrated Monitoring Unit (IMU) is an electronic monitoring system, enclosed in a case and attached to the battery pack end-piece. The IMU monitors the conditions of the battery pack and communicates the measured data to the BMS.

Pressure sensor
The integrated pressure sensor enables recording of battery pack pressure. This signal is used for battery pack diagnostics and for high precision charge management. The risk of venting by overcharging the battery pack is eliminated by this unique feature.

Rupture disc
Nilar battery packs are fitted with a rupture disc located on the rear side of each battery pack that is activated at a pressure of 7 bar. During normal and mildly abusive conditions, the battery pack is sealed with no emission of gases or electrolyte. In normal operation, the internal pressure of Nilar battery packs is below the activation pressure of the rupture disc.

Module
The 12 V module is the building block for all Nilar batteries. The 10 cells are connected in series to create modules with a nominal voltage of 12 V.

Contact plate
The contact plate electrically connects the adjacent modules in the pack and thus eliminates the need for external connectors between modules.

Heat dissipation
Heat generated by the cells is disspated by air draught over the contact plate surfaces of the module. The design of the battery block forces air draught between the modules in the battery pack. The air removes heat from the modules and minimizes the temperature gradient over the modules in the battery pack. Air is sucked in to the battery block through air inlets at the front of the battery block and leavs the battery block through the fan at the rear od the battery block.

Nilar reoxygenating battery blocks
A battery block consists of a battery pack, a fan, an insulation tray and cover with air flow guides. Each battery string consists of 2-5 battery blocks.

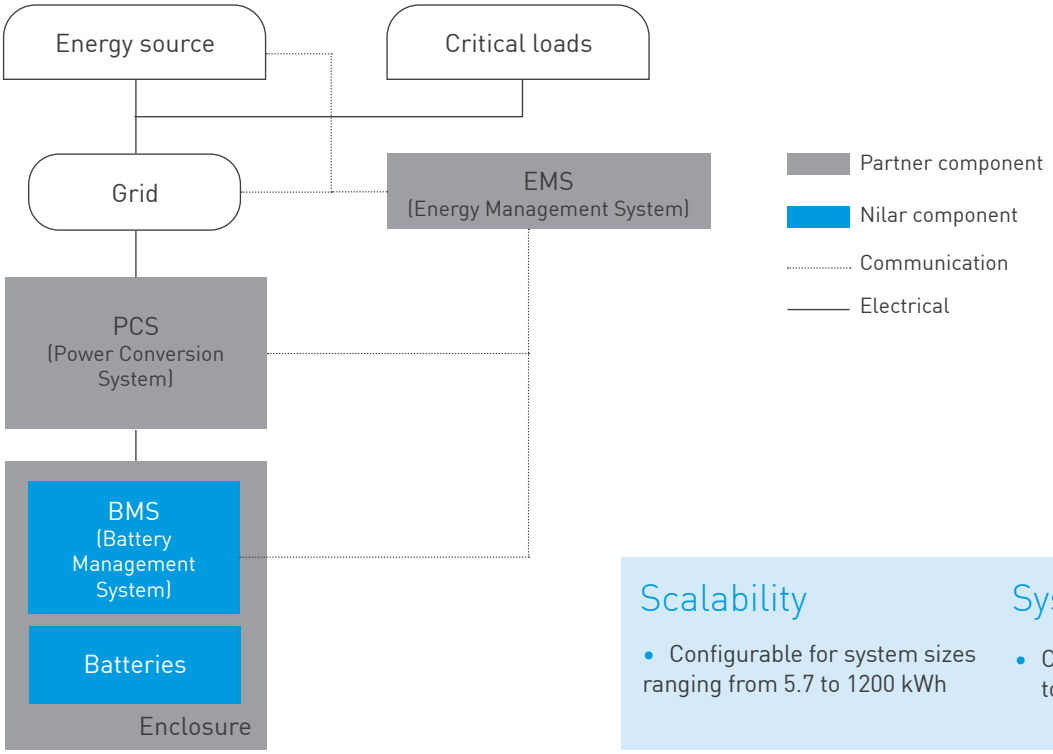
Nilar reoxygenating battery block

Nilar reoxygenating battery strings
Nilar batteries are connected as strings in series of 2-5 battery blocks to fit customer system voltage, delivering from 2.67 to 6.67 kWh per string and configurable for system sizes ranging from kWh to MWh sizes. The battery strings are controlled by a Nilar Battery Management System (BMS) for verification of specified performance.
Bild på ihopkopplade batteriblock

Nilar reoxygenating battery string

Battery Management System

The Nilar Battery Management System (BMS) monitors, controls and protects the batteries and its environment to maintain a long service life. Through its combination of software and hardware, the fine-tuned management system optimizes battery operation for best-in-class reliability, safety and efficiency at all times. Remote access enables support, troubleshooting and software updates.



Overview of energy storage system components.

Scalability

- Configurable for system sizes ranging from 5.7 to 1200 kWh

System voltage

- Configurable from 120 V to 600 V system voltage

Functions overview

Supervision:
Ability to monitor the batteries during charge and discharge operations.

Customer alert:
Alerts the customer when ReOx® service is recommended.

Cell balancing mode:
Rebalancing battery cells to ensure optimal and smooth operation.

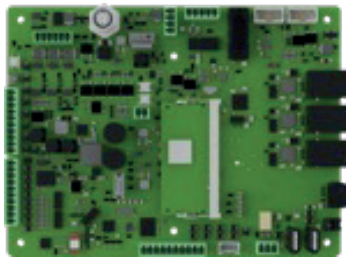
SoC:
Sophisticated state-of-charge algorithm for Nilar batteries.

Events and alarms:
Communication and tracking of battery events and operation outside of nominal parameters.

Fan control:
Ability to utilize air cooling in dynamic and efficient ways.

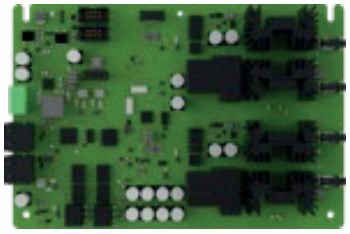
BMS Circuit board descriptions

BMS Master Unit



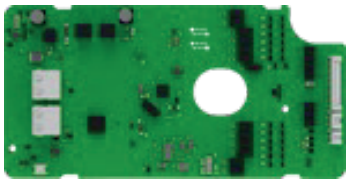
The BMU board is the communications and control hub of Nilar's BMS. The BMU is connected to the customers Energy Management System (EMS) and through this has the ability to control the contactors, communication with batteries, safety features and data sent to the EMS. The BMU has the overall control of all String Control Units (SCUs) in the system. Furthermore, the BMU can log data and enables remote updates of the BMS. Apart from this, the BMU controls the power and can get input data from several external devices such as contactors, insulation monitoring devices and residual current monitors.

String Control Unit



The main use for the SCU is to connect and disconnect the strings, measure current in the strings, measure voltage over the string switch and collect data from the Integrated Monitoring Unit (IMU). It also controls the FCU (Fan control unit), supplies 5V to the IMU and the FCU (not 24V for fans). It also provides the lower safety link from the IMUs and the FCU boards and the upper safety link between the SCU and the BMU board. Each SCU can handle up to 10 IMUs , equal to 10 battery packs, and 2 FCUs.

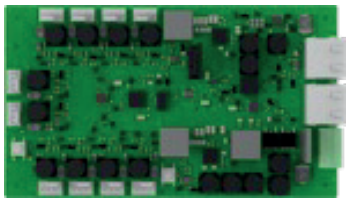
Integrated Monitoring Unit



The main purpose of the IMU is to measure voltage, temperature, and pressure in the battery pack. The secondary side of the IMU board is connected to the battery pack. To be able to monitor the data, the primary side communicates with the SCU board. The voltage monitors detect the voltage of each module and battery pack.
An internal battery pressure sensor measures the relative pressure in each battery pack, relative to the outside. Due to common gas space in the Nilar bipolar pack design, all the cells in the battery pack have the same pressure. There is one temperature sensor in each battery pack that measures the temperature at the midpoint of the battery pack.

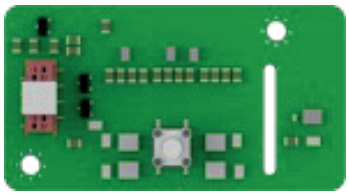
The communicated information also has the purpose to detect when a full charge cycle is completed.

Fan Control Unit



The FCU is used to control fans for cooling of packs. Each pack has its own fan and the FCU can control up to 10 fans. The FCU uses pulse-width modulation (PWM) to control fan speed and is designed for 12V DC fans with PWM control input and tacho output to monitor the speed of the fan. Each fan has its own control channel and can be controlled and monitored individually.

Humidity LED Interface



The HLI board is designed to communicate through its on-board RGB LEDs to convey actions that the BMS is currently taking, and if any attention is required from an external party. It includes a tactile switch and measures the ambient temperature and relative humidity surrounding the card. The measurements and inputs are sent to the BMU which monitors the data and acts on user input.

BMS communication interfaces

The customer interfaces are located on the BMU. There are provisions for communication over Ethernet, CAN and RS-485. Communication protocols such as Modbus TCP or RTU, CANOpen etc. can be implemented as needed using any of these interfaces. As standard a Modbus TCP protocol will be provided. The internal and external communication interfaces for the Nilar BMS are described in the table below.

TYPE	BETWEEN SYSTEMS	COMMUNICATION & PROTOCOL
Internal	BMU to SCU	CAN-FD (with Nilar internal protocol)
Internal	SCU to IMU	CAN (with Nilar internal protocol)
Internal	SCU to FCU	CAN (with Nilar internal protocol)
Internal	BMU to Negative and Positive Contactors	I/O with Feedback (hardwired)
Internal	HMI to BMU	I2C
External	BMU to Energy Management System	CAN, Ethernet or RS485
External	BMU to Internet	Ethernet

BMS overview technical data

PARAMETER	INFORMATION/VALUE
Designed max DC voltage	800 Vdc
Communication ports	Ethernet, CAN, RS-485
Communication protocols	Modbus TCP/IP, Modbus RTU (upon request) and CANopen (upon request).
Temperature range for BMS components	-20 to +70 °C
Overvoltage category	III
Electrical standards	EU LVD 2014/35/EU, EU EMCD 2014/30/EU
Pollution degree	2
Possible nominal voltage range	120 to 600 Vdc
Minimum configurable system size	1.2 kWh
Maximum configurable system size	1.2 MWh
Battery voltage measurement accuracy	+/- 0.5%
Battery voltage measurement time	-3 ms
Battery current measurement accuracy	+/-30 mA or +/- 1.2%
Battery temperature measurement accuracy	More than 99.5 %
Absolute temperature measurement error	+/- 2 °C

Specifications of the BMS cards

COMPONENT	BMS MASTER UNIT	STRING CLUSTER UNIT	HUMIDITY LED INTERFACE	FAN CONTROLLER UNIT	INTEGRATED MONITORING UNIT
Abbreviation	BMU	SCU	HLI	FCU	IMU
Function	The BMU is the controller hub and has the overall control over the BMS.	The SCU board that control two strings and measure the current and handles the strings connection to the system.	Measures surrounding temperature and humidity, has an LED indicator to communicate BMS status	The FCU board that controls and powers the fans individually.	The IMU board that is placed on the battery and measures battery data as module voltage, temperature, and pressure.
Topology level	1	2	1	2	3
Operating voltage	24 Vdc +/- 4 Vdc	24 Vdc +/- 4 Vdc	5V +/- 0.5V	24 Vdc +/- 4 Vdc	5.3 +/- 0.5 Vdc
Current consumption at 24V supply	< 220 mA	< 220 mA	< 60 mA	< 75 W	< 130 mA
Output voltage	19 to 28 Vdc	< 800 Vdc	N/A	12 Vdc +/- 0.3 Vdc	N/A
DC current throughput	350 mA per output, 2A total	40 A	N/A	N/A	N/A
Supported temperature range, °C	-20 to +70	-20 to +70	-20 to +70	-20 to +70	-20 to +70
Overvoltage category	N/A	III	N/A	N/A	III
Pollution degree	2	2	2	2	2
Power consumption, watt	5.04	5.04	4	0.34	0.4

Integration

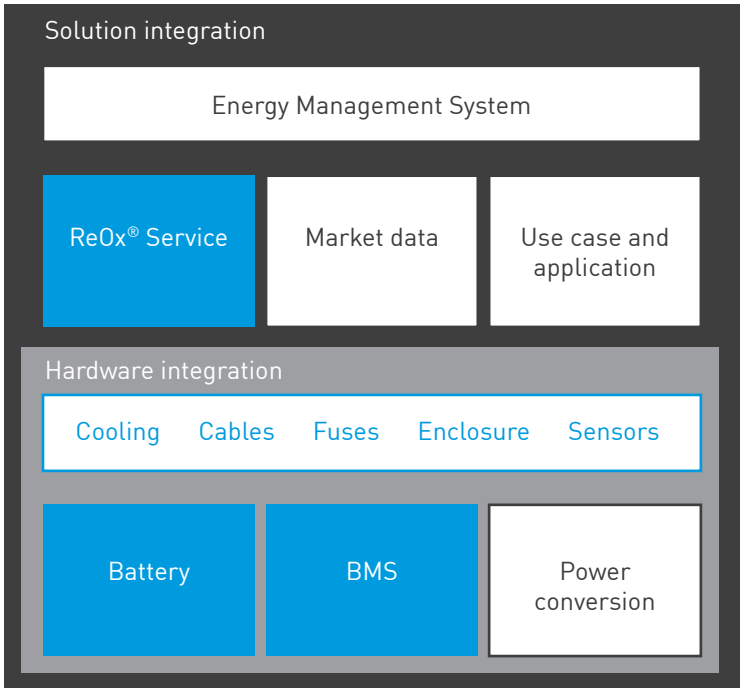
If you're an energy storage system manufacturer, adding Nilar ReOx® batteries to your solution is an easy way to do good while doing what's best for you and the planet. A great step towards offering energy storage users substantial sustainability and safety benefits intended to ease the green energy transition.

Partner benefits

As a Nilar system integration partner you obtain exclusive business-building opportunities based on your needs, including advanced training, promotional resources and expedited service from our dedicated support staff.

Dedicated integration support

Nilar enables safe and sustainable energy systems through our pioneering battery technology, with a focus on developing and producing batteries, control systems, and patented life extending technology. With our passionate team of dedicated battery professionals we can contribute with our expertise and knowledge to support you throughout the whole integration and launch process of your energy storage solution.



Nilar offer

Battery

This is the Nilar Hydride battery included in the reoxygenating product series. Different battery units with varying energy capacity are available.

BMS

Nilar provides a complete solution of both hardware and software interfaces between the battery and external control systems. It includes an embedded circuit board design with electrical control posibilites as well as measurement devices. It also includes redundancy for the monitoring and safety of the batteries through a separate circuit.

ReOx® service

In order to utilize the Oxygen filling technology of the reoxygenating product series it needs to be considered in the design and operation of the energy storage system (ESS). Ease of access to the batteries after installation and properly implemented functionality within the EMS is needed. Nilar provides information on how the functionality is to be implemented within the communications protocol as well as how the ReOx service should be implemented in the supply chain.

Operating performance

Charging

Charging can be made with various charge power and ambient temperature levels, as specified for the product. For test purposes the recommended charge procedure is constant current charge with charge termination based on temperature increase rate (dT/dt), pressure and pack temperature.

An inherent feature of the Nilar Hydride® electrochemical system at charging is the build-up of pressure and temperature at the end of the charge. The unique battery pack pressure sensor, integrated in Nilar battery packs, together with measured battery pack temperature, are efficient means to secure charge termination over the whole temperature and power range. At low temperatures, the charge rate can be limited by an increased voltage. At elevated temperatures, the maximum charge rate is limited by the rise in temperature and pressure at end of charge

Self discharge

The state-of-charge (SOC) of a Nilar battery pack during storage slowly decreases with time due to self-discharge. The self-discharge is caused by internal electrochemical side reactions that slowly discharge the battery. The self-discharge rate is high over the first days of storage, but then levels out to a few percent per month depending on temperature. The rate of self-discharge is increased at elevated temperatures and decreases at low temperatures. Parasitic loads on the battery from charger, load and electronic systems will increase the rate of capacity loss during storage.

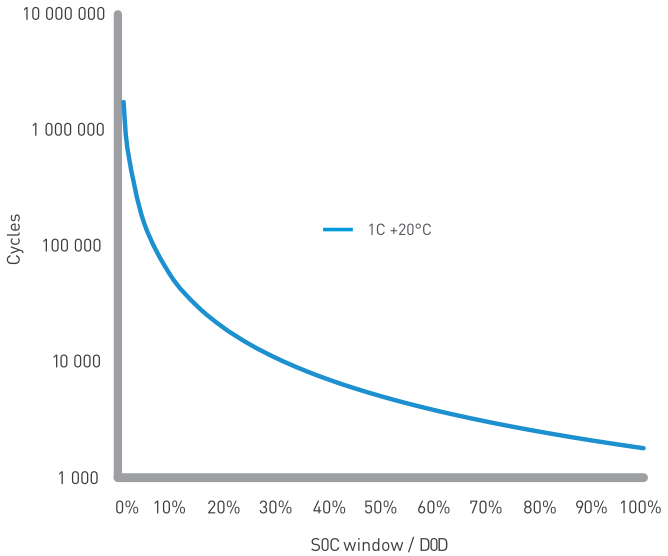
Cycle life

Cycle life is the number of charges and discharges a battery can achieve before the discharge capacity drops to a predetermined capacity. A number of circumstances have to be considered when estimating cycle life. Among the most important are temperature, charge method, charge and discharge rates, depth-of-discharge (DOD) and environmental aspects. The largest impact on the cycle life comes from the battery pack temperature, the charge procedure, and the SOC operating window. The more shallow a battery is cycled, the higher the number of cycles until the battery is unable to sustain the required service.

One of the superior features of Nilar batteries is the very stable performance over life. Typically, the impedance of a battery increases when the battery is used. This results in reduced run time and finally, depending on how end of life is defined, the battery is not able to perform as required. The

stable and well defined performance over life experienced with Nilar batteries is a consequence of the intrinsic features of the Nilar Hydride® technology together with the high manufacturing quality gained by the Nilar patented bipolar design. The main ageing mechanism is dry-out, causing a slow increase in impedance over cycles.

Capacity is not deteriorated during cycling. Nilar Hydride® batteries can be stored for many years without loss of performance. There is no decomposition of the electroyte at full charge nor solid electrolyte interface consuming charge carriers with detrimental effect on capacity and impedance. Cell impedance in a Hydride (NiMH) cell is determined by the amount of electrolyte in the separator. Over time, the electrolyte in the separator decreases (dry-out) with a slow decrease in conductivity. Finally, depending on the load, the run time of the battery is down to a level where the battery is considered as spent. End-of-life is often defined as 80% of initial capacity but can be based on other application specific constraints or capacity levels.



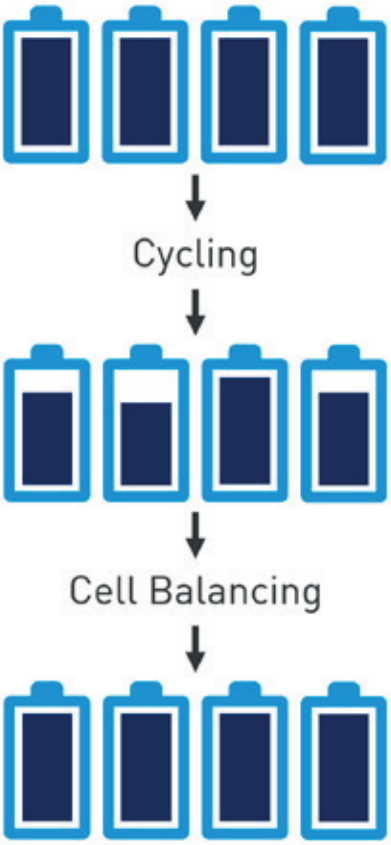
Cycle life as a function of SOC window.

Cell balancing

All batteries in a system are not identical; they often have small differences in energy capacity. When each string is connected, the batteries are matched to make sure that each string contains batteries that are the utmost alike.

In operation, as a battery string is cycled, the SOC of the individual batteries may become uneven over time, causing a very slight lowering in capacity. Although these varied levels may be imperceptible, the imbalance can accumulate through continuous cycling and will eventually be detectable.

Fortunately, a process called cell balancing can be used to reestablish the equilibrium. This functionality is intrinsic to Nilar's battery management system and is present as an easily activated maintenance routine. When triggered, the batteries are steadily charged to 100% SOC, and then undergo a few short sequences of pulse charges. This pushes any batteries that may have lowered back to their original maximum capacity, bringing the system back to its best possible performance. When cell balancing is complete, the system is fully charged and ready to return to normal operation



Nilar reoxygenating series
The sustainable choice

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to find out more about our products and find our local offices.

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