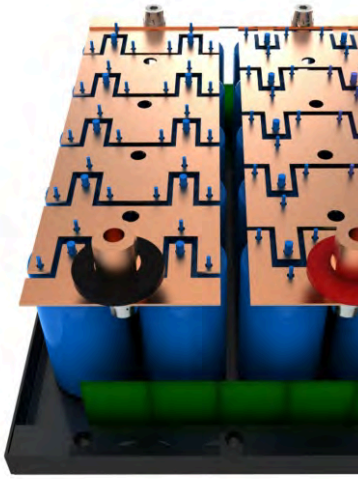
MADE IN GERMANY



WIMA PowerBlock Modules

www.wima.com

WIMA PowerBlock-Modules

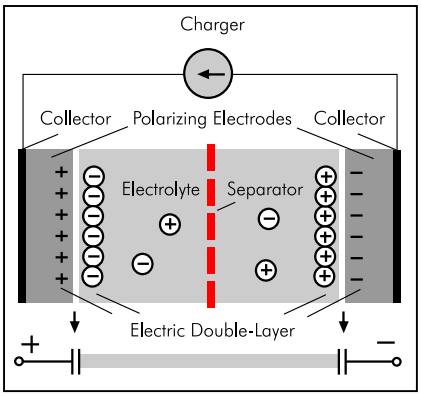
Innovative Alternative to Energy Storage Using Batteries

Passive components, especially capacitors, nowadays undergo constant futher development, and therefore make an indispensable contribution to technical progress in electronics. Every day we use innovative solutions with an increasing number of new functions being checked, controlled or actually even made possible by electronics.

One of the most recent innovations in the field of passive components is the electrochemical double-layer capacitor.

Based on the Helmholtz principle of energy storage in the electrochemical double-layer of electrolyte systems it can take up energy of e.g. several thousand Joule which is comparable to the stored energy of small batteries.

Construction Principle



Construction principle of a double-layer capacitor

The construction of a double-layer capacitor can be described as a plate capacitor where the focus is to obtain electrodes with an extremely large surface. The electrolyte, the conductive liquid between the electrodes, is a conducting salt dissolved in a aqueous or organic solvent. The double-layer consists of ions which, when voltage is applied, attach to the positive or negative electrode corresponding to their opposite poles and thus create a dielectric gauge of a few Angstrom only. A permeable membrane serves as separator and thus avoids short circuit between the electrodes. The very huge surface of the electrode results in a very high capacitance yield. To visualise this, the internal surface of a double-layer capacitor would cover a football pitch.

Cascaded PowerBlock Modules

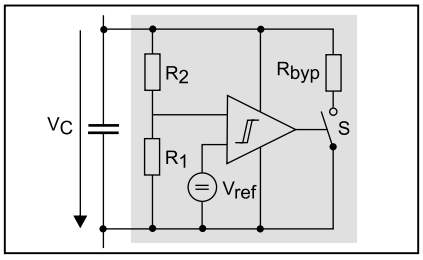
Several double-layer capacitors can be built up to an enormous capacitance of the desired voltage by means of series or parallel connection (cascade). When cascading, the nominal voltage of the individual cells must not be exceeded (decomposition of the electrolyte!). Hence, series connections need in any case to be balanced since a possibly slightly different aging of the individual cells due to temperature may over time cause deviating capacitances and thus different voltage drops at the cell. The balancing will be factory-mounted into the module. This can be made passively and in a cost-efficient way by simple resistors in those cases where additional losses as bypass current through the balancing resistors can be tolerated by the application. Alternatively, an active balancing can be made by keeping each cell at a certain voltage by means of a reference source. That means if the comparator circuit detects a commencing overload of any cell individual discharge is initiated by a bypass resistor.

Passive Balancing:

Without resistor: U inversely proportional to C - thus local overvoltage can easily occur.
With resistor: U proportional to R - thus voltage is fixed.

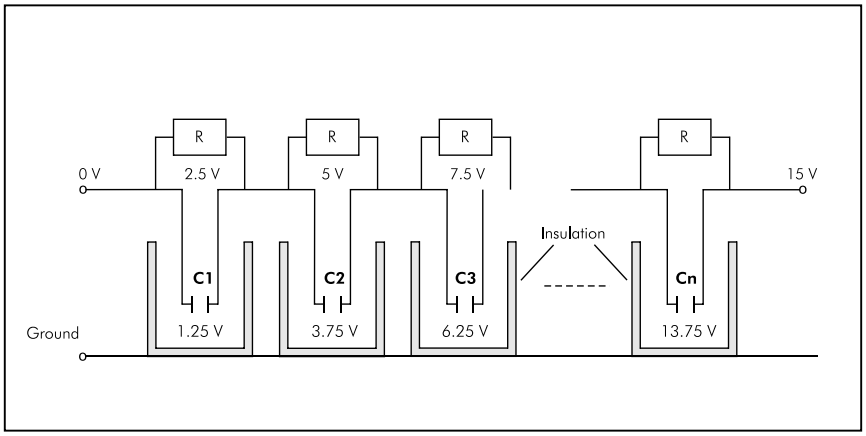
Active Balancing:

Comparator compares voltage drop at the capacitor by a reference voltage and switches for discharge through a bypassing resistor until overvoltage has declined. Except the leakage current of the cells there are no considerable losses created during active balancing.



Advantages in Comparison with other Energy Storage Solutions

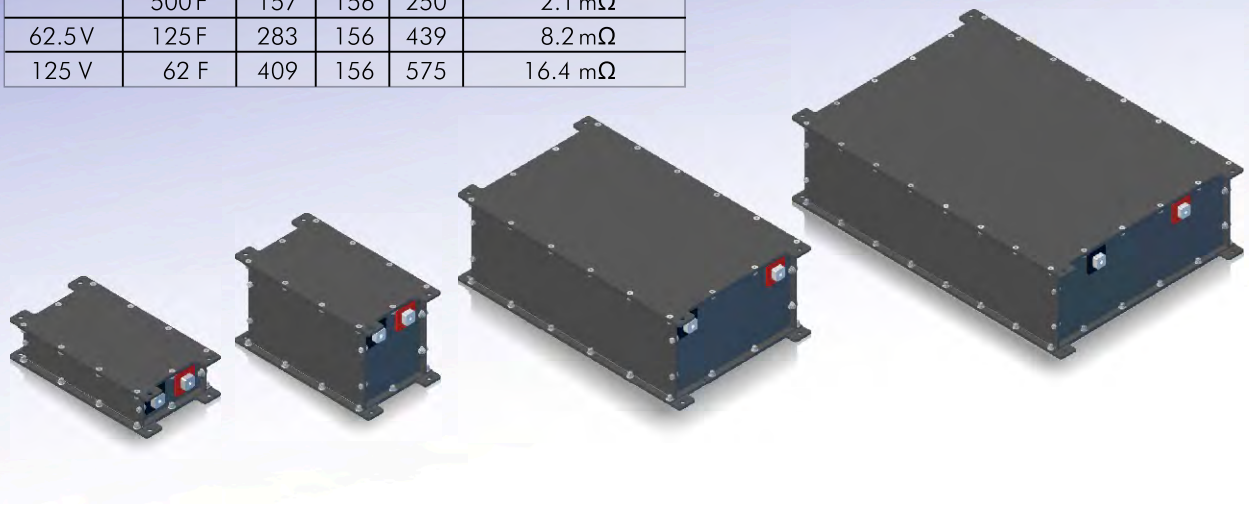
In general double-layer capacitors are used for voltage support, for fast supply of electrical energy e.g. to cover the peak



Without resistor: U inversely proportional to C - local overvoltage can easily occur
With resistor: U proportional to R - voltage is fixed

Standard WIMA PowerBlock Modules

U_R	C_N	Dimensions W	H	L	Max. ESR_{DC}, initial
16 V	105 F	157	69	250	5.2 mΩ
	500 F	157	156	250	2.1 mΩ
62.5 V	125 F	283	156	439	8.2 mΩ
125 V	62 F	409	156	575	16.4 mΩ



power requirements, or for protection of batteries which as a result can be designed smaller as the capacitor buffers the current peak. The typical application is quick supply of several 100 A to 1,000 A in the direct current field.

WIMA PowerBlock modules based on double-layer capacitors combine the advantage of conventional capacitors as fast suppliers of electricity and batteries as notable energy reservoirs. Contrary to energy storage by batteries, the charging voltage represents the energy content and thus a sudden voltage collapse does not occur with PowerBlocks.

Other benefits versus conventional batteries and rechargeable battery solutions include maintenance-free operation and a relatively low weight, thus usage in isolated systems, e.g. inaccessible areas, is unproblematic above all since WIMA PowerBlock modules are resistant to high temperature changes, too. When properly treated they have a service life beyond 10 years and can easily sustain more than 1,000,000 charge/discharge cycles, with the efficiency being far higher than 90%. Compared to other storage media, the risk of destruction by total discharge is excluded for WIMA PowerBlocks.

Fields of Application for WIMA PowerBlock Modules

Motor Start

WIMA PowerBlock Modules replace, protect or support converntional batteries to reliably crank big diesel engines in e.g.:

- **Trucks**
- **Construction, agricultural and earth moving machines**
- **Busses and trains**
- **Vessels**
- **Generators**
- **etc.**

During start-up of a big diesel engine the energy requirement is quite high. By using WIMA PowerBlock modules the battery layout can be designed smaller and thus lower in weight which leads to a significant reduction of fuel cost and emission of harmful substances.

Railway Technology

WIMA PowerBlock modules store braking energy and immediately release it for engine starting, acceleration or peak-load levelling in e.g.:

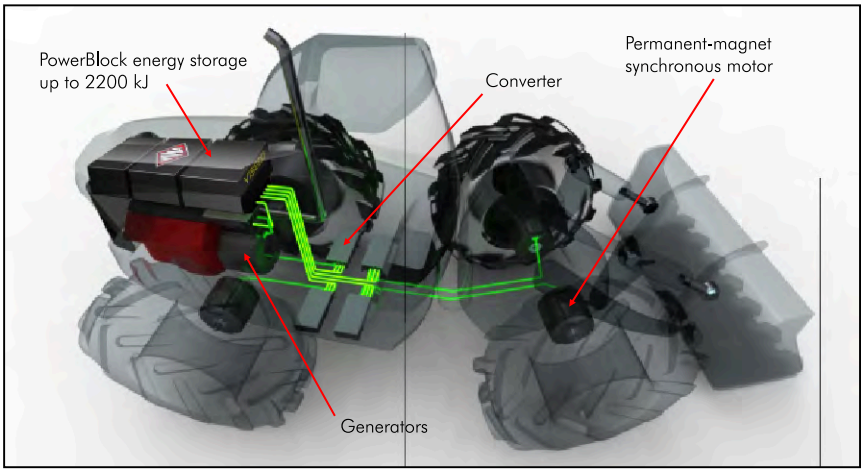
- **Locomotives**
- **Electric tramway**
- **etc.**

The use of PowerBlock modules as energy storage increases efficiency and life time of transportation systems, saves weight and cost for maintenance, and is environmentally friendly.

Hybrid/Heavy Transportation

WIMA PowerBlock modules in hybrid drives support diesel engines with fast and frequent dynamic loads in e.g.:

- **City busses**
- **Construction machines, agricultural machines and forestry equipment**
- **Forklifts, cranes**
- **etc.**



VISEDO electrified wheel-loader using WIMA PowerBlock energy storage modules

The use of WIMA PowerBlock modules as energy storage leads to significant saving in terms of fuel consumption and considerably reduces exhaust and noise emission.

Automated Guided Vehicles (AGV)

WIMA PowerBlock modules serve as rechargeable or exchangeable energy storage in independent, automated guided vehicles (AGV) in e.g.:

- **Warehouse and distribution environments**
- **Production facilities**
- **In-plant logistic systems**
- **etc.**

The use of PowerBlock modules as energy storage saves weight, reduces cost for maintenance and increases efficiency and life time of the transportation system.

Uninterruptible Power Supply (UPS)

Cascaded WIMA PowerBlock modules are used as emergency power supply in e.g.:

- **Hospitals**
- **Telecommunication systems**
- **Oil production plants**
- **Gas extraction**
- **etc.**

By reliably bridging short-term power outages cost-intensive system crashes can be avoided.

High current source based on WIMA PowerBlock modules

Wind Power Systems

WIMA PowerBlock modules are applied in mains-independent drives of wind power plants in e.g.:

- **Slip control**
- **Angle altering of rotor blades**
- **Rotation speed control**
- **etc.**

Due to the considerable temperature variation in the wind turbine nacelle, these storage devices have to meet stringent requirements. Because of their significant maintenance, service life and weight benefits compared to battery solutions, WIMA PowerBlock modules considerably increase the efficiency of those systems.

Customized Solutions
WIMA Competence

WIMA has many years of experience in construction of customized energy storage modules based on double layer capacitors. Design and construction of individual solutions is coordinated with the user. Customer's advantages are:

- High expertise due to 10 years of manufacturing and field experience
- Individual design related to
  - environment
  - space requirements
  - fixing
  - connecting options
- Flexible capacitance or voltage due to serial or parallel cascading of single cells with 350 F to 3,000 F
- Laser-based, reliable welding of the single cells
- Robust, vibration resistant construction according to IP-25 - IP-69 K on demand
- Various technical options, e.g.:
  - temperature monitoring
  - overvoltage signal
  - voltage monitoring
  - industrial connector/CAN-connector
  - application-adapted cooling
  - custom-specific protection class
- Pulse current, endurance and voltage tests accord. to IEC 62576 or DIN EN 62391-1
- Prototype and small series production
- Ready for connection supply.

Customized Solutions:
Hybridisation of Diesel Engines

Although construction, agricultural and forestry machinery is still dominated by diesel and hydraulic drives hybridisation fairly suggests itself.

Almost all construction, agricultural and forestry machines, dockside cranes, forklifts, busses and ships mistreat their diesel engines in a staccato of full load and idle speed and by the way drive the heavy vehicles. If the frequently occurring load peaks are buffered electronically cost, consumption as well as the emission of exhaust and noise are reduced considerably.

The limits for particulate filters, nitrogen oxides and hydrocarbons for off-road vehicles have been drastically reduced by

the EU since 2001: Was it several grams each of those air pollutants per kWh that were permissible at that time, with the final Tier 4 level in 2014 the values were reduced to tenths and hundredths of grams.

Hence, more efficient drive solutions are required e.g. realized with energy storage solutions based on WIMA PowerBlocks.

Example 1: ROCKSTER parallel hybrid crasher.

Due to hybridisation the diesel engine operates nearly constant at optimal speed to drive the generator for the electric motor. Any load peaks are cushioned by WIMA PowerBlocks which buffer the energy. All components are water cooled and meet the stringent requirements of the application conditions. They are specifically designed for usage in mobile construction machines and protected against dust, dirt and water. Moreover they are resistant to vibration and extreme temperature fluctuations.

Example 2: Wheel-loader with VISEDO hybrid drive.

Heavy wheel-loaders have diesel engines with a power of around 300 kW which drive both the wheels and the hydraulic system. Due to their dual function they rarely run in their optimum operating map - above all since wheel loaders rather shunt than make distances. But actually diesel engines are too slow in reaction for this purpose. This is totally different with electric motors: Within milliseconds they supply full engine torque from off-condition, load-cycle changes are run more efficiently, and when actuated exactly they enable the traction to be dosed in a way to ensure that the wheels don't spin even on muddy ground. And all this happens almost noiseless which relieves driver, workers and residents in the same way.

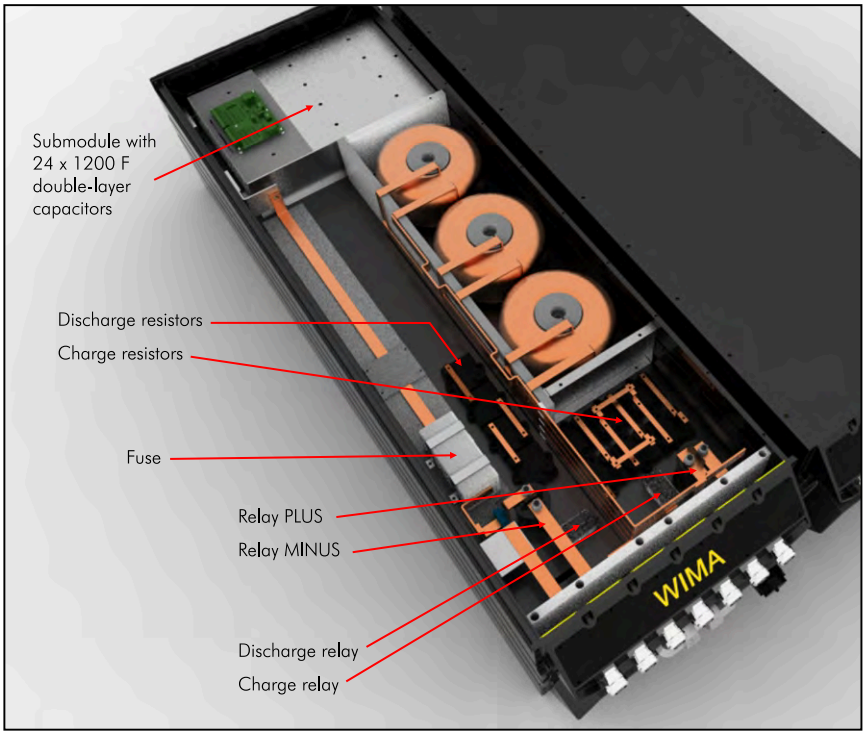
A wheel-loader with a diesel engine of only 120 kW instead of 300 kW would be in a position to use these advantages. It runs at almost constant rotation speed and drives a 125 kW generator generating an AC current which is converted to DC current by a 300 A converter for four 75 kW electric motors being installed close to the wheels which drive the wheels and brake regeneratively. They are controlled by a 200 A inverter which at the same time conducts the regained braking energy towards the PowerBlock storage modules exhibiting an energy of one Mega Joule.

In this way, advantages in consumption of 25 % have thus been achieved in customer projects. As the fuel consumption of heavy construction machinery, harbour cranes or agricultural machinery frequently is 20 litres per hour the saving adds up to 20,000 litres of diesel at 4,000 operating hours with the CO_2 emission being reduced to almost 53 tons per year. Hence, hybridisation will pay for itself within two to four years because compared to cars there is one major advantage: as during operation of mobile machinery there are numerous short power peaks it is low-priced capacitors that buffer the power instead of costly batteries. This makes hybrids more affordable and saves the environment. Also cost of maintenance is reduced since almost maintenance-free electric motors absorb the dynamic loads.

Because of the enormous power peaks and adverse environmental conditions hybridisation of mobile machinery means high demands to the components which have to be encapsulated against dust, dirt and water in accordance with the stringent IP standards respectively and submitted to vibration tests with 10 G and bump tests at 50 G.

The design of the WIMA PowerBlock energy storage modules has from the beginning been developed to fulfill the requirements in mobile heavy duty applications.

- Modular design allowing the flexibility to fit the product into application needs
- Designed especially for highly cyclical loads in heavy mobile work machines
- Water or water/glycol mixture cooling
- Temperature range -40...+65 °C
- Class IP-69 encapsulation
- Up to 97% efficiency
- High permissible ambient temperature and long life-time >90,000 hours
- Integrated CMS (Capacitor Management System) including control, protection, supervision and communication functions (CANopen, SAE J-1939)
- User-friendly maintenance and service interface.



Concept of an energy storage for hybridisation of a diesel engine

Customized Solutions:
Power Supply Stations

High current sources required as test devices or for transformation in metallurgy can now be designed by using WIMA PowerBlocks taking advantage of characteristics which have not been available before. The low internal resistance of double-layer capacitors which are offered by WIMA in cascaded construction makes them ideally suited to withstand highest current pulses for periods of seconds.

Picture 1 presents a construction for discharge as of 230 V at 3000 A for 1.5 sec. 4 modules of 100 F/56 V each are vertically positioned and connected in parallel in the bottom area of the cabinet and thus represent 25 F altogether. The internal resistance of this array is lower than 33 mΩ. This construction is provided with a copper terminal cross section of 150 mm². A commercially available charger with current limitation is used by the customer for charging. The module housings themselves are grounded.

For service purposes during cabinet erection the equipment is additionally fitted with an internal discharge device consisting of a power FET switch activating a discharge current of approx. 10 A when the non-release voltage is switched off at the switch in the door. Thus the discharge constant is about 8 minutes. Proper charging condition is signalized by a voltage display.

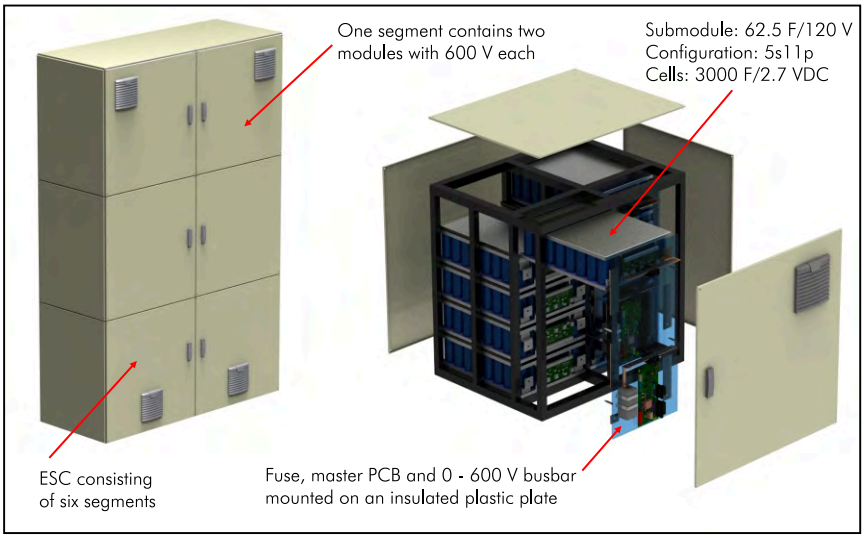
If requested by customer the modules can be supplied with active or with passive balancing. Moreover, a diagnostic signal for overvoltage or excess temperature can be provided.

Picture 1: Current source with 25 F and 230 V nominal voltage

- Maintenance friendliness (quick and easy replacement of individual modules within minutes only)
- Safety features (current / insulation monitoring, implementation of fuses, etc.)
- Monitoring of the individual strings and cells (temperature, voltage)
- Compact design.

Schematic design of a current source with a capacitance of 137 F and 600 V nominal voltage

Picture 2 shows an energy storage with 5 pcs. 62.5 F / 120 V modules being connected in series to one rack of 600 V, and 11 racks being connected in parallel to reach high capacitances. This construction serves to supply a power of 600 kW within 20 sec. During construction of the energy storage special emphasis was placed on:

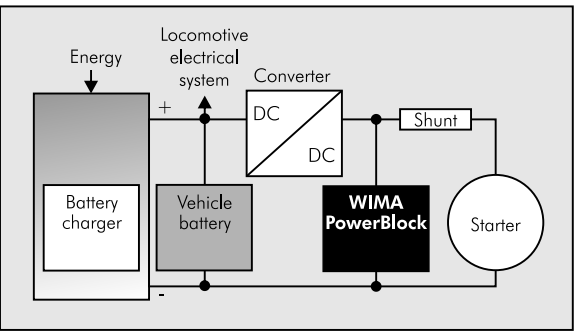


Picture 2: Current source with 137 F and 600 V nominal voltage

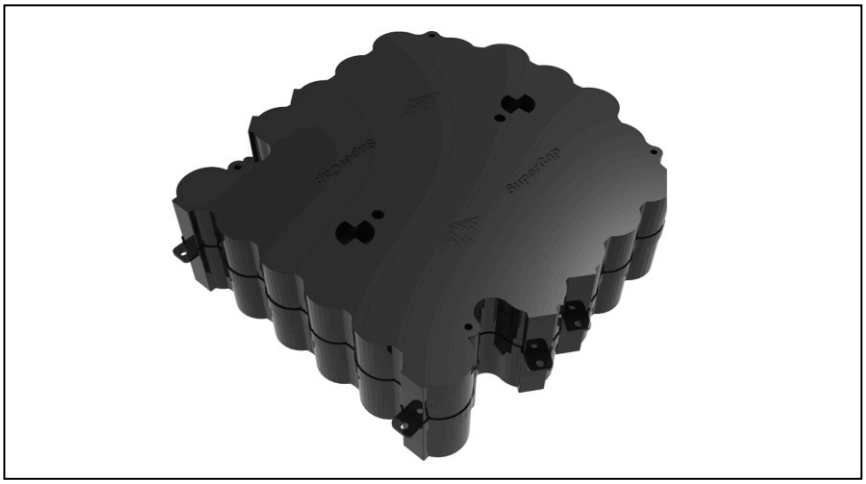
Customized Solutions:
Start of a Diesel Engine or a Micro-Turbine

Starting of V16 or V24 cylinder motors (6000 kW), e.g. for a generator drive of diesel electric trains or start of diesel engines for vessels requires high currents; 1300 A are quite usual (during the initial breakaway torque even considerably more). Frequently the crank shaft is turned from both sides by two starters (e.g. 7 kW each with forced switch-off after 9 sec for 2 min) to avoid torsion of the big mass.

Because of their significant maintenance, service life and weight benefits, WIMA



PowerBlock modules are more and more replacing customary starter batteries.

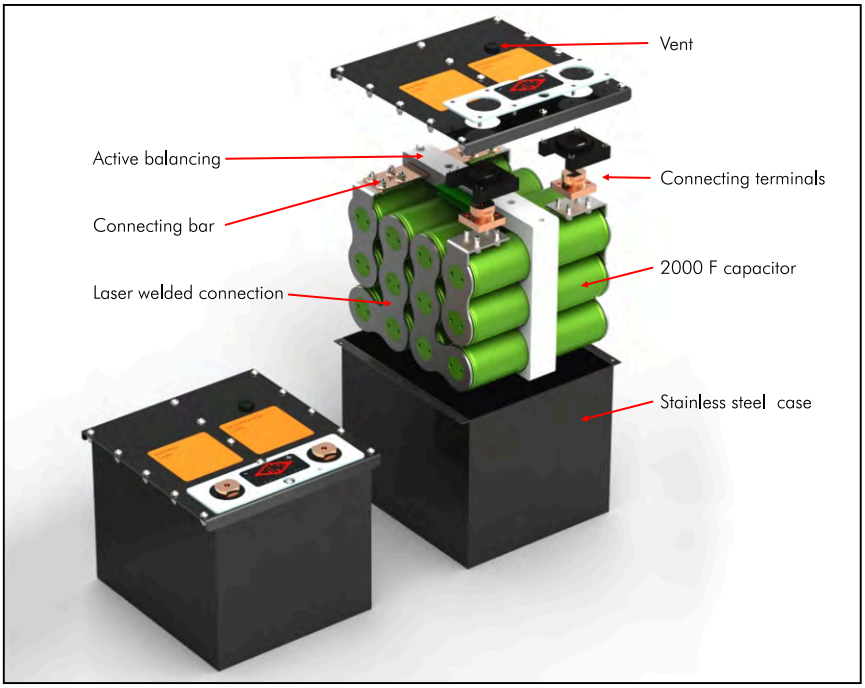


Pitch drive for wind power applications with 14 F and 165 V nominal voltage

The capacitor module is only about 1/10 in weight compared to a conventional battery solution and thus permits an increased operating distance of up to 25 % due to additional fuel that can be carried.

Recuperation of braking energy

Generally a vast amount of kinetic energy is wasted when braking. This temporarely generated high energy can be stored by WIMA PowerBlock modules and be made available again when required.



Construction principle of a motor starter with 333 F and 28 V nominal voltage

Customized Solutions:
Slip Controller in Wind Turbine Systems

In large wind power plants a slip control for each pitch is used which is designed to change the pitch angle of the blade and thus affects the rotation speed. When too strong winds occur the pitches will e.g. be turned into the wind to completely cut off propulsion. The pitch drives are mains-independent and if electrically controlled use the energy stored in batteries or double-layer capacitor modules. Due to the considerable temperature variation in the wind tower top housing, these storage devices have to meet stringent requirements. During winter time temperatures around -40° C frequently occur in the nacelles, and during summer time more than +60° C can easily be reached during operation. The current load of more than 200 A required for the initial breakaway torque of e.g. 3 kW engines causes big problems to batteries under such conditions. For those applications WIMA PowerBlock modules score with higher performance in terms of life time, maintenance cycles and weight.

Conclusion:

WIMA PowerBlocks are future-proof components offering customized solution approaches for many requirements in modern electronics. They are solely manufactured in Germany and offer a high degree of flexibility in design and performance. Genuine “Made in Germany”.

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Operational Data of PowerBlocks
Betriebsdaten für PowerBlocks

BASIC DATA / *BASIS DATEN*

Company name / *Firma:*
Address / Adresse:
Person responsible / *Sachbearbeiter:*
Contact information / *Kontaktdaten:*

Application / *Anwendung:*
Potential quantity p.a. / *Bedarfsvorschau p.a.:*
Start of project / *Projektanlauf:*

TECHNICAL DATA / *TECHNISCHE DATEN*

Rated voltage / *Betriebsspannung:*	U_{max}		[V]	U_{min}	[V]
Rated current / *Betriebsstrom:*	I_N		[A]		
Max. pulse current / *Max. Pulsstrom:*	I_P		[A]		
Energy required / *Energiebedarf:*	E		[A]		
Charge time / *Ladedauer:*	t		[s]		
Discharge time / *Entladedauer:*	t		[s]		
Ambient temperature / *Umgebungstemperatur:*	T		[°C]		
Max. operating temperature / *Betriebstemperatur:*	T		[°C]		
Life time expectation / *Nutzungsdauer:*	t		[h]		

Max. number of charge/discharge cycles: ☐ (per sec. ☐ per min. ☐ per hour ☐)
Max. Anzahl der Lade- und Entladezyklen *(pro Sek. pro Min. Pro Stunde)*

Balancing / *Zellensymmetrierung:* Passive ☐ Active ☐

Requested delivery version: Module ☐ Rack ☐
Lieferausführung

Max. size available / *Max. verfügbarer Platz:* ☐ x ☐ x ☐ [mm]

Special requirements: (Temperature monitoring unit, fuses, etc.)
Besondere Anforderungen *(Temperaturüberwachung, el. Sicherungssysteme etc.)*

Date / *Datum:*

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