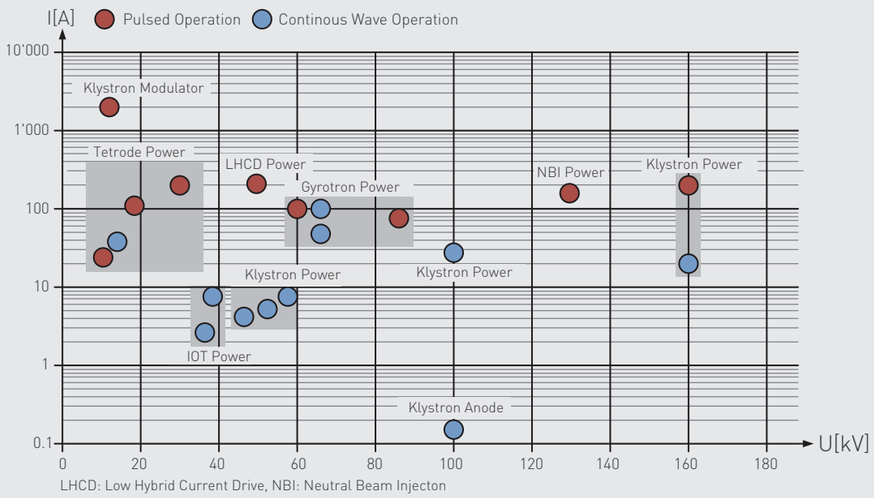
High Voltage Power Supplies | List of References

Modulator for XFEL	Country	Application	Units Delivered	Rating	Contract Date
AccSys	USA	Anode Modulator for Klystron (Linear Accelerator)	1	90 kV, 120 A	2016
Tri Alpha Energy	USA	Fast Switching Coils Power Supply	2	5.1 kV, 6 kA	2016
		Fast Switching Coils Power Supply	2	2.5 kV, 6 kA	2016
IPP W7X, Greifswald	Germany	Gyrotron & NBI (Plasma Heating)	1	130 kV, 70 A	2015
Budker Institute	Russia	NBI (Plasma Heating)	1	40 kV, 55 A	2015
Tri Alpha Energy	USA	Trim Coil Magnet Power Supply	8	850 V, 6 kA	2015
		Saddle Coil Power Supply	4	850 V, 6 kA	2015
KIT Karlsruhe	Germany	Gyrotron Test Stand	1	90 kV, 120 A	2014
		Gyrotron Test Stand	1	40 kV, 120 A	2014
GSI Darmstadt	Germany	Tetrode (Heavy Ion Synchrotron)	14	15 kV, 20 A	2014
ESS	Sweden	Klystron (Linear Accelerator)	1	110 kV, 50 A	2014
Budker Institute	Russia	NBI (Plasma Heating)	1	40 kV, 55 A	2014
Fusion for Energy	Spain	Gyrotron & ECRH (Plasma Heating)	8	55 kV, 100 A	2013
		Gyrotron & ECRH (Plasma Heating)	16	35 kV, 100 mA	2013
PSI Villigen	Switzerland	Modulator for SwissFEL	1	370 kV, 344 A	2013
DESY Hamburg	Germany	Modulator for XFEL	2	12 kV, 2 kA	2013
Triumf	Canada	Klystron (Linear Accelerator)	1	65 kV, 9.3 A	2013
DESY Hamburg	Germany	Modulator for XFEL	5	12 kV, 2 kA	2012
RRCAT	India	Klystron (Accelerator)	1	100 kV, 25 A	2012
Triumf	Canada	Klystron (Linear Accelerator)	1	65 kV, 9.3 A	2012
AccSys	USA	Klystron (Linear Accelerator)	1	58 kV, 12 A	2011
PSI Villigen	Switzerland	Tetrode (Cyclotron)	4	15 kV, 40 A	2011
PAL Pohang	Korea	Klystron (Synchrotron Light Source)	1	55 kV, 12 A	2011
DESY Hamburg	Germany	Modulator for XFEL	22	12 kV, 2 kA	2011
Brookhaven National Lab	USA	IOT (Synchrotron, Booster)	1	38 kV, 4 A	2010
Brookhaven National Lab	USA	Klystron (Synchrotron Light Source)	2	55 kV, 12 A	2010
LAL Orsay	France	Modulator for XFEL	1	8.2 kV, 1.5 kA	2009
PAL Pohang	Korea	Klystron (Synchrotron Light Source)	2	55 kV, 12 A	2009



LHCD: Low Hybrid Current Drive, NBI: Neutral Beam Injecton

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Science MedTech Industry Broadcast

AMPEGON

The Heartbeat of High Power

High Voltage Power Supplies

ampegon.com

High Voltage Power Supplies

Ampegon designs and delivers stand-alone regulated high voltage power supplies for high energy applications in pulsed and cw mode

Ampegon has long experience with RF amplifier systems, high voltage as well as high current power supplies and modulators for world-class medical, industrial and research facilities. Our customers include particle accelerator and fusion research institutes, fundamental and applied physics, materials and life sciences engineering, notable providers of accelerator-based cancer treatment solutions, as well as innovative partners enhancing industrial processes. Offering its innovative and pioneering spirit with expertise of a century, Ampegon products stand for premium quality, reliability and best performance.

Unique Expertise and Innovation
Our expertise includes stand-alone high voltage power supply (HVPS) systems with voltages up to 200 kV and currents up to 2000 A, RF amplifier systems up to 55 MW power at frequencies up to s-band, short and long pulse modulators with voltages over 500 kV and currents up to 400 A, and stand-alone multi-channel digital low level RF control systems. Our technology base extends across the entire field of RF transmission.

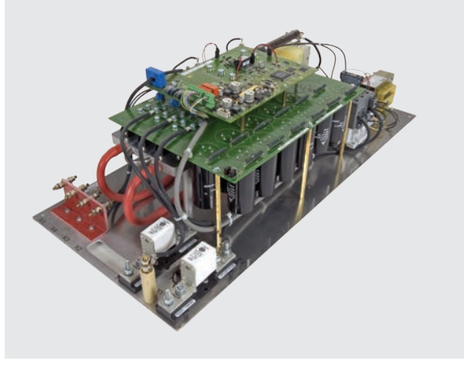
At the heart of the stand-alone high voltage power supply (HVPS) system is the Ampegon patented pulse step modulator (PSM).

Ampegon developed the PSM in the 1980's as a solid state replacement for vacuum tube based audio modulators in radio broadcast transmitters. Ampegon recognized the potential of this technology for cw as well as pulsed systems with variable pulse length and has designed and taken into operation dozens of modulators for pulse durations between 100 µs and 15 s in the power range from kW up to 32 MW.

Unlimited Flexibility
Ampegon HVPS solutions are esteemed for their highest flexibility. Thanks to the modular design of the basic PSM and the enhanced PSM (EPSM) technology, systems are adaptable to meet practically any customer specification and need.

Environmental Compatibility
With very high peak energy levels, accelerator facilities are dependent on a highly stable mains power supply and very low EMI figures. The specified mains input current is regulated in such a way as to keep the mains consumption at a constant level. The excellent harmonic distortion characteristics assure that loading of the mains with harmonics is kept to an absolute minimum. Typically PSM modulators are designed for a direct conversion of the required voltage, which may be as high as 200 kV. The required pulse current can be as high as 2000 A.

System Optimization
Unique features of the PSM include crowbarless operation, even for most sensitive loads; short-circuit switching-off time of less than 5 µs; and typical short-circuit energy of less than 5 Joules. Ampegon PSM technology makes consequent use of system redundancy. This and the equal loading of all power modules, results in low component stress and high component lifetime. Thanks to the modular design, PSM systems can be scaled to meet practically any specifications.

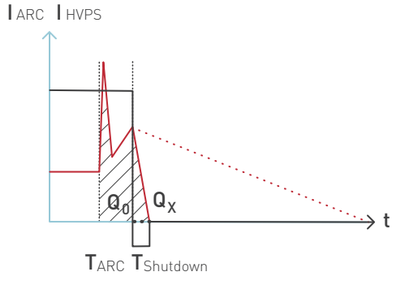


PSM Plug-In Modules | Each module is carefully checked at the factory before integration in the PSM rack. The photo shows a water-cooled PSM module especially suited for use in areas with problematic atmospheric conditions, like corrosion, salt, pollution, dust, etc.

Long Pulse HV Modulator | Prototype for the European XFEL project.

PSM power modules are available in different current ratings starting at 150 mA up to 2000 A in either air cooled or water cooled versions. The use of Ampegon PSM technology enables a considerable reduction of energy and operating costs as compared to other modulation techniques. With a high efficiency of better than 97%, and high power factor, Ampegon PSM systems make an important contribution to environmentally benign and cost-efficient operation.

Since the introduction of the PSM technology in the 1980's the technology has been continuously enhanced and improved. A major step in this evolution is the introduction of an additional DC/DC converter on the PSM module which leads to the new EPSM topology. By using an EPSM topology the input power can be kept to constant levels even for pulsed applications. The voltage ripple is significantly decreased, the behavior in case of load transients is improved and the system size is reduced. Another significant novel is the inverse voltage operation. PSM system equipped with this additional operation mode feature extremely low arc energy. Figures below 1 J can be reached easily.



Output signal of a 2-Q system in case of an arc (dotted without inverse operation) | The dotted red line shows the behaviour without inverse operation mode. The blue line shows the output voltage of the HVPS.

TINE based control system displaying a pulse.

Typical Technical Data HVPS System	
Efficiency	≥ 97 %
Short Circuit Switch-Off Time	< 5 µs
Short Circuit Energy	< 5 Joule
Output Voltage Accuracy	< 0.2 %
Mains Power Factor	> 0.95
Control Bandwidth	> 50 kHz
Rise and Fall Times	< 30 µs

The Data in the above table are typical data
The dynamic behaviour, the ripple specifications and energy into arc may change according to the needs of application.

Key Features

- Voltages up to 200 kV
- Current up to 2 kA
- DC and pulsed systems
- High reliability thanks to redundancy
- Outstanding mean-time-between-failures (MTBF) figures
- Long lifetime due to equal thermal module loading and module design
- Crowbar less operation
- Short circuit energy at the load <5 J / inverse voltage operation <1 J
- Short (5 µs/160 kV) and continuously ad justable rise time
- Low overshoot characteristics
- High pulse accuracy, due to flexible pulse forming capabilities
- Pulse flatness (± 0.2 %)
- Low flat top ripple (± 0.2 %)
- Voltage accuracy (0.1 %)
- Wide modulation capability up to 20 kHz
- Continuously adjustable duty cycle for pulsed operation (0 – 100 %)