Ampegon Solutions: Systems in Use

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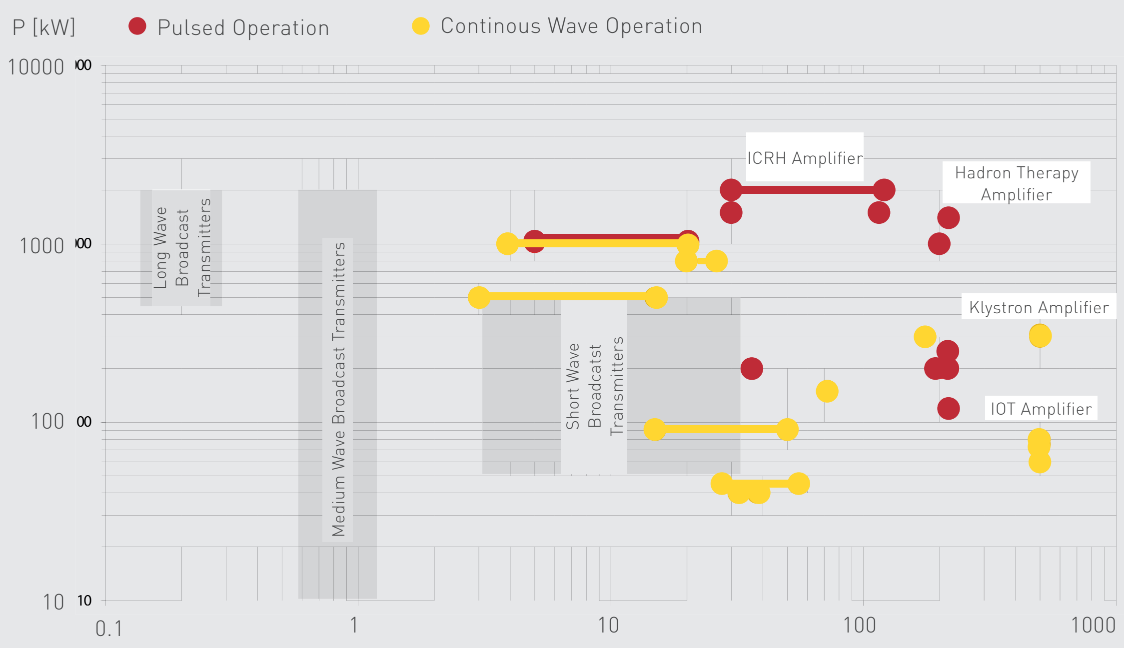
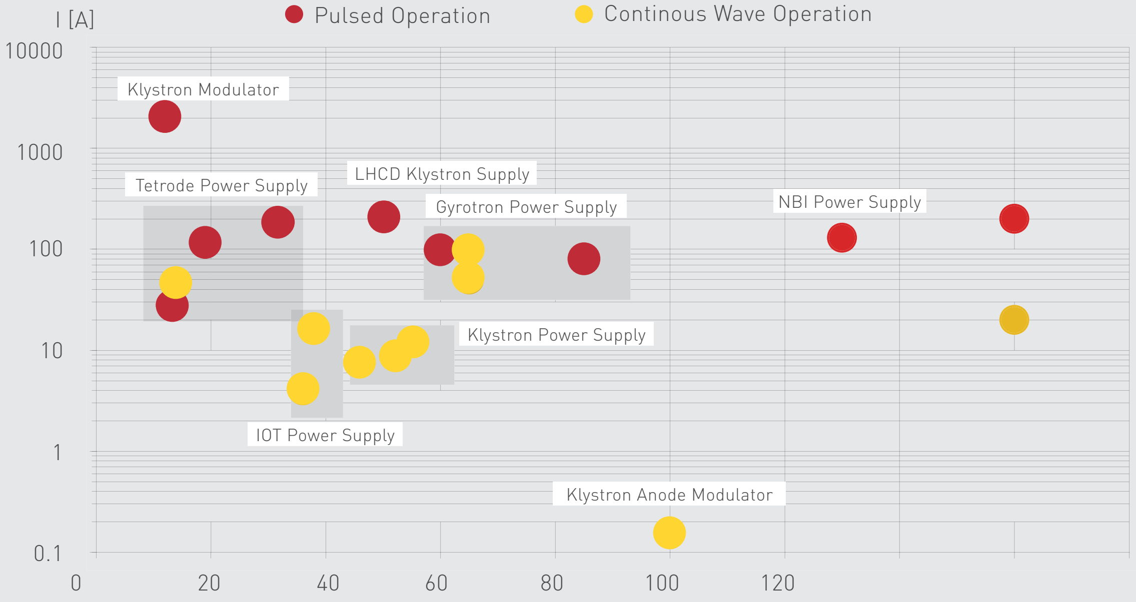


Ampegon RF Amplifer Solutions
ICRH: Ion Cyclotron Resonance Heating, **ECRH**: Electron Cyclotron Resonance Heating.



Ampegon HVPS Solutions
LHCD: Lower Hybrid Current Drive, **NBI**: Neutral Beam Injection.

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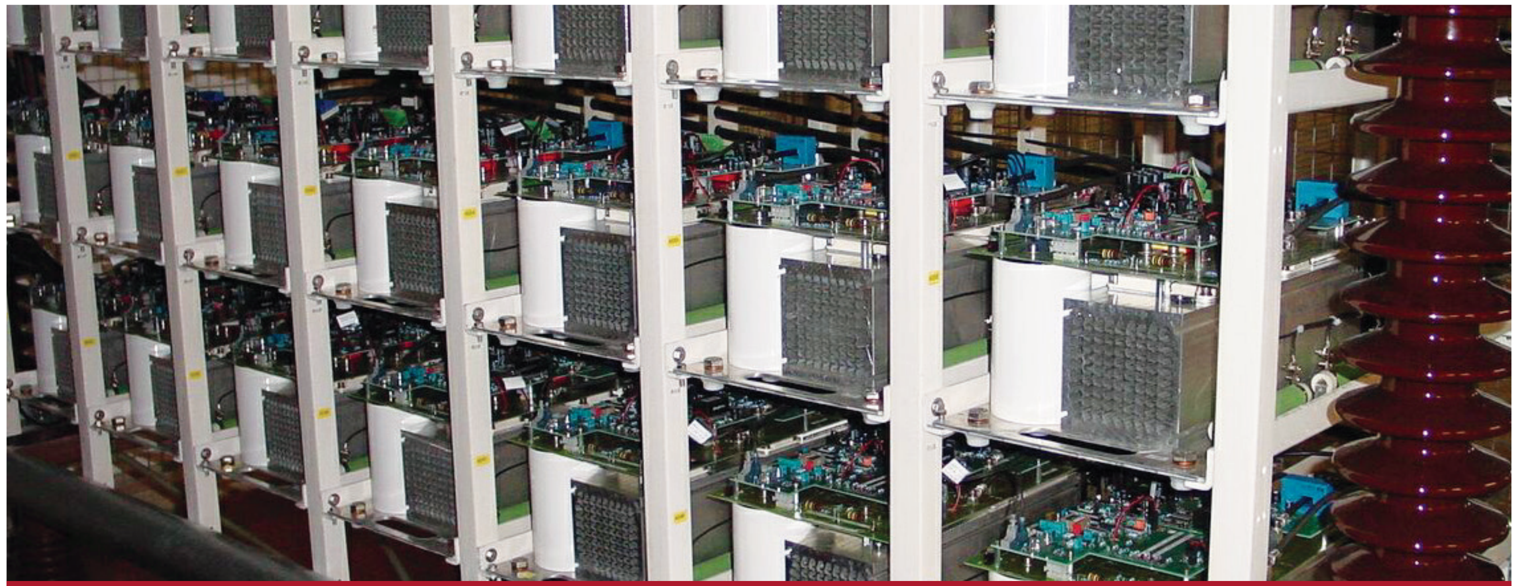
Science MedTech Industry Broadcast

AMPEGON

The Heartbeat of High Power



Wendelstein 7-X

Case Study

Wendelstein 7-X

Deep within the Wendelstein 7-X nuclear fusion research center, high voltage power sources from Ampegon are helping to pave the way for a brighter future

Since 1983, Ampegon designs and delivers flexible, reliable and scalable HVPS and RF amplifiers systems to fusion research facilities around the world. The Ampegon systems provide the power for the plasma heating systems, such as Electron Cyclotron Resonance Heating (ECRH), Ion Cyclotron Resonance Heating (ICRH) and Neutral Beam Injection (NBI).

A main goal of fusion research is to demonstrate the viability of the generation of long-term, safe and environmentally benign energy through nuclear fusion. Fusion is a particularly attractive energy solution as it uses fuels that are abundant and available around the globe. The primary fuel for fusion is an ionized, low-density gas – a plasma – composed of deuterium and tritium. To induce fusion, the plasma must be heated to an ignition temperature of 100 million degrees. Since any contact with the walls of the heating vessel would cool down the plasma, magnetic fields are applied to confine and thermally insulate the plasma and keep it away from the vessel walls.

Max Planck Institute for Plasma Physics (IPP) is a physics institute concerned with investigating the physical principles underlying a nuclear fusion power plant, which – like the sun – will produce energy from the fusion of light atomic nuclei. With its workforce of approx. 1100, IPP is one of the largest fusion research centers in Europe. Max Planck Institute for Plasma Physics is associated with the European Fusion Program and the Helmholtz Association of German Research Centers. The IPP has two sites: Garching (founded 1960) and Greifswald (founded 1994).

Wendelstein 7-X experiment currently in implementation at the Greifswald Branch of IPP intends to demonstrate that nuclear fusion devices of the stellarator type are suitable for power plants. IPP selected Ampegon's high voltage power supplies to provide the power for the plasma heating systems based on their high flexibility, reliability, highest performance and long lifetime.

On its way to a power plant fusion, research is concentrating on two different types of experiment: the tokamak and the stellarator. Most of the devices in the world today are of the tokamak type, which is best investigated and comes closest to the ignition conditions. Both types feature ring-shaped magnetic fields. Tokamaks produce part of these fields by means of an electric current flowing in the plasma. Stellarators, on the other hand, form the magnetic field cage solely by means of external coils. Stellarators are thus suitable for continuous operation, whereas tokamaks without auxiliary facilities can only work in pulsed mode. IPP is the only fusion center in the world investigating both types of experiment. This allows direct comparison. The research conducted at IPP is concerned with investigating the physical basis of a fusion power plant.

For this purpose IPP is conducting at Garching the ASDEX upgrade project, a large-scale experiment of the tokamak type. At its Greifswald Branch, IPP is building the so-called Wendelstein 7-X (W7-X) stellarator. This project will test a magnetic field optimized to overcome the difficulties of previous stellarator concepts. The quality of plasma equilibrium and confinement will be comparable to that of a tokamak. The predecessor of W7-X, Wendelstein 7-AS (1988 – 2002), was the first experiment of the new generation of «advanced stellarators» and put this concept for an improved magnetic field to the first test. W7-X, the further developed follow-up device, is now to demonstrate the reactor relevance of the new stellarators.

ASDEX Project at IPP Garching

For the ICRH program at the Garching ASDEX tokamak, Ampegon delivered two RF amplifier systems with 1.5MW each. These were taken into operation in 1985. In 1986, IPP Garching ordered four more units from Ampegon with 2 MW each for their new ASDEX-UPGRADE project. The upgrade in power and frequency range resulted in a complete re-engineering of the amplifier stages. Two of the amplifiers were also used for the stellarator Wendelstein 7-AS.

Technical Specifications RF Amplifier Systems for ASDEX Tokamak Project	
Output Power	1.5 MW
Frequency	30 – 80 MHz
VSWR	1.0
Output Power linearly derated to	1.0 MW
Frequency	80 – 115 MHz
VSWR	1.0
Pulse Duration	10 sec.
Average Power	50 kW

Technical Specifications RF Amplifier Systems for ASDEX-UP-GRADE Project	
Output Power	2.0 MW
Frequency	30 – 80 MHz
VSWR	1.5
Output Power linearly derated to	1.0 MW
Frequency	80 - 120 MHz
VSWR	1.5
Pulse Duration	10 sec.
Average Power	60 kW

New Approach for W7-X at IPP Greifswald

W7-X design calls for several types of plasma heating systems with high output power and high demand for accuracy and multi-configurability. The three heating systems include:

- An Electron Cyclotron Resonance Heating System (ECRH) with totally 10 MW output continuous wave (cw) with 10 tubes (gyrotrons)
- A neutral beam injection (NBI) with a pulsed output power of up to 3 MW per accelerator and up to 100 short circuits per second in conditioning mode
- An ion cyclotron resonance heating (ICRH) with a pulsed output power of 2 MW per RF amplifier

A special challenge was posed by the system specifications, which called for a single power supply for all three heating systems. To meet these specifications, Ampegon designed universal high voltage power sources with a total of 26 MW electrical power in continuous wave operation and 52 MW in pulsed operation. The Ampegon HVPS systems are based on the Ampegon patented pulse step modulator (PSM). Thanks to the modular design of the basic PSM technology, the HVPS systems are adaptable to meet practically any customer specification and need. Unique features of the PSM include crowbarless operation, short-circuit switching-off time of less than 5 µs, and a typical short-circuit energy of less than 5 Joules.

PSM Transformer Arrangement | The PSM transformer provides the AC power to each PSM module in the switching module assembly of the HVPS units.

A new Peak in the Application of the PSM Technology

Ampegon PSM technology makes consequent use of system redundancy. This and the equal loading of all modules, results in low component stress and high component lifetime. 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.

For the W7-X project, Ampegon designed three HVPS systems for NBI and ECRH, rated 0 – 130 kV, 50 A cw and 0 – 130 kV, 130 A pulsed. The fourth system was designed for ICRH or ECRH with a rating of 0 – 65 kV, 100 A cw or 0 – 65 kV, 160 A pulsed.

Since not all the heating systems are in operation simultaneously, it did not make sense to use individual power supplies for each system. The proposed solution provides high flexibility and comprises two different switched mode power supplies, each able to supply two different load types. To allow an optimum flexibility for different output voltage levels, the power supplies were designed for series connected operation, thus providing continuously variable voltages between 5 kV and 130 kV in both polarities.

Milestone in HVPS Technology

The power supplies implemented for this project exceed the output voltage, current and power of all such systems taken into operation so far and represent a new peak in the application of this technology.

The total cw power of one supply could be driven up to 6.5 MW per module. The output voltage is with 130 kV the highest ever done with this technique. The output current of 50 A continuous wave and up to 160 A in pulsed operation, the modular design and the highly flexible controller makes this technique attractive for practically any high voltage high power application having high demands on dynamic behavior.

An important project milestone was reached beginning 2004 when Ampegon handed over the four systems. This opened the door at Greifswald to the begin of extensive gyrotron testing.

In 2016 Ampegon has again been contracted for two additional high voltage power sources and the upgrade of the existing four systems with Ampegon's advanced UCS control system. The temperature and energy-state of the resulting plasmas will be improved by the increased power output.