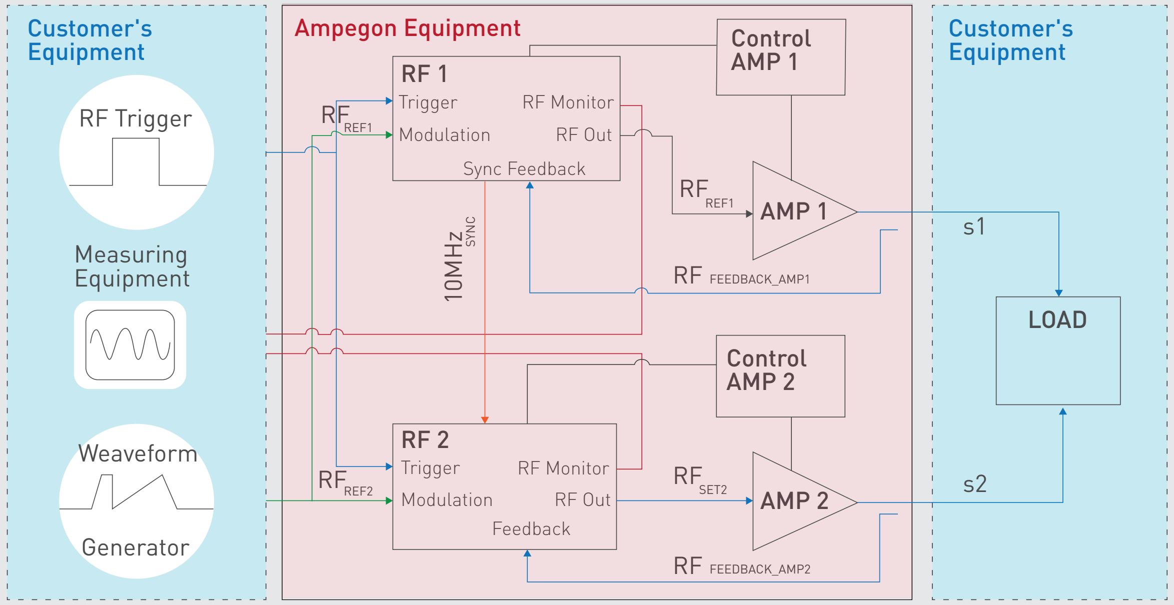
Release Date 2012

Block Diagram



Specifications

Key System Data

Frequency Range	4- 20 MHz continuous, automatically tuned
RF Power	40 kW cw, 3 – 200 kW pulsed at 10 % duty cycle
VSWR	∞ plasma formation phase (first 10 ms), 1:1.5 normal
Modulation possibilities	5 kHz sinus, 2 kHz square
Spurious	< -40 dBc

LLRF Source and Regulating System Data

Connector	Explanation	Specification
External Trigger Input	Enable/disable to RF output	XLR3 female, low level = 3 V, high level = 6.5 V
Sync	10 MHz reference output or 10 MHz reference input for synchronous operation	3.5 dBm, 50 Ω 13 dBm max., 50 Ω
RF Output 1	Amplitude controlled RF output signal. Depending on the operation mode it is either pulsed or continuous	BNC, 4 – 20 MHz, 50 Ω, 0 – 14 dBm
RF Output 2/RF Monitor	CW RF output signal (not pulsed) at the same phase and frequency as the RF Output 1. Can be used for monitoring purposes	BNC, 4 – 20 MHz, 50 Ω, 0 – 14 dBm
RF Feedback	Feedback signal, used by the controller in closed-loop operation	BNC, 30 MHz bandwidth, 50 Ω, 4 dBm max.
Modulation	Analog Amplitude-Reference Input	XLR3 female, 0 – 5 VDC, 15 kHz bandwidth
Local Control Remote Control	LCD display with keyboard Serial remote control Interface for the Amplifier Control system	RS422

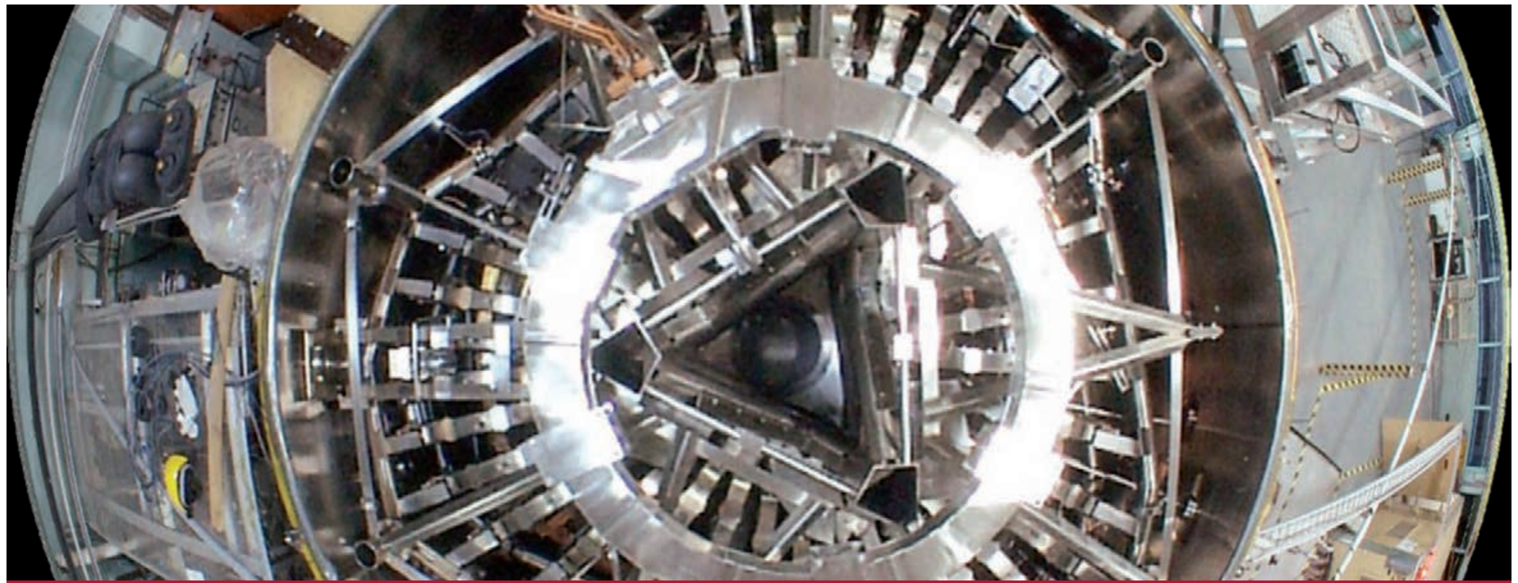
Contact

Ampegon Power Electronics AG
Kreuzweg, 11 | CH-5400 Baden, Switzerland
Tel. +41 58 710 44 00
info@ampegon.com | ampegon.com

Science MedTech Industry Broadcast

AMPEGON

The Heartbeat of High Power



Australian National University

Case Study

ampegon.com

Australian National University (ANU)

Investigation of basic plasma physics and exploration of ideas for improved magnetic design of the fusion power stations

The Australian Plasma Fusion Research Facility is a uniquely versatile plasma research facility, located in the Research School of Physics and Engineering within the Australian National University (ANU) in Canberra. As part of the super science initiative, $ 7 million has been allocated to the upgrade of Australia's plasma fusion research capabilities.

A core component of the facility is the H-1 Heliac plasma confinement device (Heliac). The Heliac allows investigation of basic plasma physics and exploration of ideas for improved magnetic design of the fusion power stations that will follow the ITER international fusion experiment in France.

Scope of the RF Upgrade

Upgrading the original medium power RF heating system:

- The system used to generate plasma in the H-1 has proven to be the most often-used method of plasma formation and heating, because of its flexibility of modulation and ability to control the phase elements in the antenna
- That system is almost 50 years old, is becoming increasingly unreliable, and is the main cause of unscheduled facility down time
- The upgrade will double the available power, improve reliability and facility uptime, and reduce electric power costs
- Furthermore, the ability to vary frequency over a wide range will allow properly controlled magnetic field scans while using resonant heating

RF Amplifier

The RF amplifier is based on the existing well known standard 100 kW shortwave transmitter TSW 2100D. It was specially customized as this system requires a frequency range from 4 to 20 MHz. In addition the RF amplifier can also provide the necessary power range from 3 to 200 kWp that the plasma heating system requires. The RF driver stage is a semiconductor wide-band amplifier that supplies an output power of 1.2 kW into a 50 ohm load. The matching of the driver stage to the final stage grid is achieved by a tunable π-section network.

The final stage using a tetrode type TH 581 is operated in a conventional grounded cathode configuration. To reach the minimum power levels without exceeding the tolerable power in the screen grid the tube's operation point set to class AB. This operating point leads to an approximate linear output characteristic which can be easily linearized by the RF regulating system. With the RF regulating system it is possible to adapt the specifications for low and high pulse power levels as well as modulated pulses, to the customer requirements.

A rectifier supplies the DC voltage for the screen grid. While the anode itself is supplied with a constant DC voltage from the output of the pulse step modulator PSM. This supply is deliberately decoupled with respect to RF feedback using a 2-section filter network. A tunable output network is used to convert the anode load impedance to the unbalanced 50 ohms output impedance and to filter the harmonic components from the fundamental. A directional coupler is fitted inside the RF amplifier near the output and feeds a corresponding forward and reverse power indication to the control system and the regulated RF source.

LLRF Source and Regulating System

Precise digital regulation is essential for a plasma heating system as well as for producing high quality RF pulses. As a result Ampegon has designed a special LLRF (low level radio frequency) source which includes an RF regulating and monitoring function.

This source is basically a standard RF synthesizer with additional regulating and operating functions to give ANU the highest flexibility and various possibilities to operate the amplifiers. The closed loop control circuit uses the modulation input as a reference value and the output of the amplifier as a feedback signal and controls the amplitude of the RF output with highest accuracy.

Synchronous operation of the two LLRF sources by the use of the integrated reference clock is possible as well as entirely independent operation. In addition the phase shift between the RF outputs can be set from -180° to +180°.

These features were requested in particular by the plasma research scientists for accurate timing of the RF pulses. A number of selectable monitoring outputs can be used for external measuring and diagnosing equipment. For triggering the LLRF source an external trigger input is available which is mainly used for synchronous operation; but internal triggering is also possible.

The modulation input can be used as an amplitude reference in order to modulate the RF pulse in an approximate bandwidth of 5 kHz. As such, the customer can apply waveforms according to their requirements. With the new high power amplifier and the dedicated LLRF source, ANU is capable of accessing a wide range of plasma configurations or shapes within their facility.

Accessory Equipment

Besides the two high power RF amplifiers Ampegon delivered a test load, capable for the full pulse power for testing and tuning purposes as well as additional RF equipment to set up such as a coaxial RF patch panel and directional coupler to complete the customer's setup. For remote operation two fully equipped remote amplifier control systems for each amplifier have been provided. And a dedicated interface for the customer's existing remote control system has also been designed for full integration of the new RF equipment.

After two months of installation and another six weeks of commissioning, Ampegon is proud to play its part towards the upgrade. The first major phase was marked by the creation of an Argon plasma with the new cooled antenna and RF amplifiers at 7:30 pm on Friday the 9th December, 2011. The ANU plasma research facility is now back on line comfortably in time for the 2012 academic year.

Key Benefits

- Compact designed RF amplifier with integrated LLRF system
- Highest flexibility due to power range (3–200 kWp) and wide frequency range (4–20 MHz continuous)
- Accurate regulation of high power RF pulses with LLRF system
- Two independent or synchronous RF amplifiers
- High reliability of a field proven, standard RF design
- Dedicated operation modes for specific purposes (pulsed plasma mode, cleaning mode, continuous wave mode)
- Modulation input for customized pulse envelope
- Reduced operation costs due to highest overall efficiency