Power Conversion Systems
References for nuclear fusion and particle accelerators
Jema Energy is a company specialized in the design and manufacture of power electronics solutions. The company was founded in 1953 and has supplied customized power converters to a wide range of customers in different sectors.

The product range of Jema consists of engineered UPS systems for the Energy and Oil & Gas sector, solar inverters and power quality solutions for the Energy sector and customized power converters for the Research sector such as particle accelerators, nuclear fusion, and high field magnet laboratories.

Jema has supplied equipment to many prestigious research centers.

Jema’s team of engineers and technicians can offer solutions which are engineered to meet the customer’s requirements.

Our project engineers have ample experience in managing complex projects and together with our highly qualified technicians Jema can design and deliver state of the art solutions of high quality.

Furthermore Jema’s factory is equipped with a 30kV/20MVA power connection, 17Mw resistive load and modern HV test equipment. This allows us to do extensive tests of our power supplies at very high power.

More than 60 years of history

Head Quarters in San Sebastian, northern Spain

Active presence in over 90 countries

Part of the Irizar Group

3,300 employees and annual revenue of more than $620 million

Fully dedicated R&D Center for the Energy and e-Mobility sectors
<table>
<thead>
<tr>
<th>Client</th>
<th>Project</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCFE</td>
<td>MAST upgrade</td>
<td>Neutral Beam Injector HV Power Supply</td>
</tr>
<tr>
<td>CCFE</td>
<td>MAST upgrade</td>
<td>Toroidal Field Power Supply</td>
</tr>
<tr>
<td>CCFE</td>
<td>MAST upgrade</td>
<td>Divertor Field Power Conversion System</td>
</tr>
<tr>
<td>CCFE</td>
<td>MAST upgrade</td>
<td>Low Voltage Power Supply</td>
</tr>
<tr>
<td>EFDA</td>
<td>JET</td>
<td>Neutral Beam Injector HV Power Supply</td>
</tr>
<tr>
<td>EFDA</td>
<td>JET</td>
<td>Enhanced Radial Field Amplifier Power Supply</td>
</tr>
<tr>
<td>IPR</td>
<td>ITER</td>
<td>HV Solid State Crowbar</td>
</tr>
<tr>
<td>CIEMAT</td>
<td>LIPAc</td>
<td>Tetrode HV Power Supplies</td>
</tr>
<tr>
<td>RAL</td>
<td>ISIS</td>
<td>Tetrode HV Power Supplies</td>
</tr>
<tr>
<td>CEA/ENEA</td>
<td>JT60-SA</td>
<td>High Current Power Supplies for Magnet Coils</td>
</tr>
<tr>
<td>F4E</td>
<td>JT60-SA</td>
<td>HV Power Supplies for Gyrotrons</td>
</tr>
<tr>
<td>CEA Saclay</td>
<td>Iseult MRI</td>
<td>High Precision SC Magnet Power Supply</td>
</tr>
<tr>
<td>ESS Bilbao</td>
<td>ESS Bilbao</td>
<td>Klystron Modulator</td>
</tr>
<tr>
<td>ESS Bilbao</td>
<td>SNS Oak Ridge</td>
<td>Klystron Modulator</td>
</tr>
<tr>
<td>IFIMED</td>
<td>High-Gradient RF Test Stand</td>
<td>Klystron Modulator</td>
</tr>
<tr>
<td>Client</td>
<td>Project</td>
<td>Equipment</td>
</tr>
<tr>
<td>-----------------------</td>
<td>---------------------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>ESS Bilbao</td>
<td>ITUR (Ion Sources of Ultimate Reliability)</td>
<td>Ion source power supplies</td>
</tr>
<tr>
<td>CSIC</td>
<td>FETS (Front End Test Stand)</td>
<td>High Precision Magnet Power Supplies</td>
</tr>
<tr>
<td>DESY</td>
<td>PETRA III</td>
<td>High Precision Magnet Power Supplies</td>
</tr>
<tr>
<td>CERN</td>
<td>Super Proton Synchrotron (SPS)</td>
<td>High Precision Magnet Power Supplies</td>
</tr>
<tr>
<td>IPP</td>
<td>Wendelstein 7-X stellerator</td>
<td>Control Coils Power Supplies</td>
</tr>
<tr>
<td>CRPP</td>
<td>Gyrotron plasma heating TCV tokamak</td>
<td>HV Anode Modulator Power Supply</td>
</tr>
<tr>
<td>CIEMAT</td>
<td>TJ -II</td>
<td>Various</td>
</tr>
<tr>
<td>Tokamak Energy</td>
<td>ST40</td>
<td>Toroidal Field Power Supply</td>
</tr>
<tr>
<td>Tokamak Energy</td>
<td>ST40</td>
<td>Solenoid Power Supply</td>
</tr>
<tr>
<td>Tokamak Energy</td>
<td>ST40</td>
<td>BvU Power Supply</td>
</tr>
<tr>
<td>Tri Alpha Energy</td>
<td>C2W</td>
<td>Mirror &amp; Equilibrium Coils PS</td>
</tr>
<tr>
<td>Tri Alpha Energy</td>
<td>C2W</td>
<td>Electrode PS</td>
</tr>
<tr>
<td>Tri Alpha Energy</td>
<td>C2W</td>
<td>NBI HVPS</td>
</tr>
<tr>
<td>ESS Lund&amp;ESS Bilbao</td>
<td>ESS</td>
<td>Klystron Modulator</td>
</tr>
</tbody>
</table>
The Mega Amp Spherical Tokamak (MAST) is one of the largest spherical tokamaks in the world. For the upgrade project of MAST, Jema was awarded a contract in 2008 for the supply of one HVPS of 80kV 70A used for the Neutral Beam Injector upgrade.

### Main Features
- 80kV 70A
- Duty Cycle 10s On 570s Off
- Switch off time <7μs (solid state crowbar)
- Modular solution (N+1 configuration)
- Containerized for outdoor installation
- Full power tested at factory
- Low energy stored in HV
- Low ripple

### Description of the project
The Mega Amp Spherical Tokamak (MAST) is one of the largest spherical tokamaks in the world. For the upgrade project of MAST, Jema was awarded a contract in 2008 for the supply of one HVPS of 80kV 70A used for the Neutral Beam Injector upgrade.
Description of the project

The MAST upgrade required a more powerful Toroidal Field Power Supply (TFPS) to feed the toroidal coil for magnetic confinement of the plasma. Jema was awarded the contract to design and manufacture the supply of the TFPS, including: input HV circuit breaker, matching transformers and 24 pulses rectifier. All equipment was integrated in a container for outdoor installation.

Main Features

- 133kA 4 seconds each 1800 seconds
- 340Vdc during the flat top
- 24 pulse rectifier
- Natural cooling
- Containerized solution
- Free wheel diodes (N+1) configuration

PROJECT

MAST upgrade

CLIENT
CCFE (UK)

DESCRIPTION
Toroidal Field Power Supply

COUNTRY
UK
As part of the MAST upgrade new Divertor Field Power Conversion Systems (DFPCS) were required to drive precise currents in eight pairs of the Divertor Field Coils. Jema supplied the DFPCS that consisted of 8 power supplies and a high current brake chopper.

Main Features

- 8 units of pulsed power conversion systems
- Natural cooling
- Brake chopper and crowbar included
- Inverters from ±4kA up to ±10kA
- Pulse operation 5 seconds each 1200 seconds
- Modular H Bridge configuration

Description of the project

As part of the MAST upgrade new Divertor Field Power Conversion Systems (DFPCS) were required to drive precise currents in eight pairs of the Divertor Field Coils. Jema supplied the DFPCS that consisted of 8 power supplies and a high current brake chopper.
Description of the project

As part of the MAST upgrade a more powerful Low Voltage Power Supply (LVPS) was necessary to feed the new Divertor Field Power Conversion System. Jema replaced the existing LVPS reusing some existing equipment.

Main Features

- Natural cooling
- Pulse operation 4 seconds each 1200
- 8 units of 6 pulses rectifiers, 11kA 450V each
- Series configuration
- Reutilization of the existing matching transformers
- Reutilization of the existing inter-phase reactors
- HMI included
## Description of the project

JET, Joint European Torus, is the world largest tokamak fusion machine.

Jema was awarded the supply of 2 + 4 HV Power Supplies for the Neutral Beam Enhancement.

## Main Features

- **130kV 130A, 20MVA input, 17MW output**
- Maximum overshoot < 1%
- Voltage raising ramp from 150 to 500μs
- Fast switch off time 4 μs
- 246 short-circuits at the output during 20 sec
- 260kV insulation HVHF transformers in oil
- Solid state crowbars based on LTT’s
- Water cooling system included
- Fully tested in factory

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**PROJECT**

**JET (Joint European Torus)**

**CLIENT**

EFDA – European Fusion Development Agreement (EU)

**DESCRIPTION**

Neutral Beam Injector HV Power Supply

**COUNTRY**

UK
Description of the project

JET, Joint European Torus, is the world largest tokamak fusion machine. JET required a radial magnetic field to control the vertical position of the plasma. Jema was awarded the supply of 4 Enhanced Radial Field Power Supplies +/-12kV +/-5kA to replace the existing FRFA (Fast Radial Field Amplifier).
Description of the project

ITER India will provide to ITER a set of 3 gyrotrons for the Electron Cyclotron Heating (ECH) to assist the start-up of the plasma. Jema was awarded the supply of a High Voltage Solid State Crowbar to protect the tube in case of a failure. Jema had previously supplied various solid state crowbars to other customers (CRPP (Switzerland) -85kV, JET (UK) 4 units -130kV, MAST (UK) -80kV and IPR (India) -70kV)

Main Features

- Solution based on LTT, BOD integrated
- -70kV 15A
- Turn-on delay <10μs
- Transferred energy <10J
IFMIF is a linear accelerator being built in Rokkasho (Japan) under the BA (Broader Approach) agreement between F4E and JAEA. The main objective of IFMIF is to test materials under irradiation to be validated for DEMO. In 2013 Jema was awarded the supply of 12 HV power supplies to feed the tetrodes in the RF chains of the LIPAC.

**Description of the project**

**Project**

**LIPAc (Linear IFMIF Prototype Accelerator)**

**Client**

CIEMAT (Spain)

**Description**

Tetrode HV Power Supplies

**Country**

Japan

**Main Features**

- 13kV 40A CW
- Turn-on delay < 4µs
- Transferred energy < 20J
- Crowbar protection integrated
- Input HV circuit breaker outdoor solution included
- Matching transformers outdoor solution included
- Two configurations, single or double output
Description of the project

ISIS is the world's most productive pulsed neutron source. The machine is being upgraded with a second target station in order to maintain the neutron flux at the first target it was necessary to increase the power by 25%. Jema has delivered 1 + 4 units of 400kW to replace the existing ones.

Main Features

- 20kV 20A CW
- Turn-on delay < 4μs
- Transferred energy < 10J
- Specification didn’t allow high frequency switching
- Topology similar to the existing HVPS
- Crowbar protection integrated
- Input HV circuit breaker outdoor solution included
Description of the project

JT60-SA is a Tokamak type fusion machine designed to support the operation of ITER and study the best operation of the future fusion power plants.

Jema was awarded two different contracts by CEA (France) and ENEA (Italy) for the design, manufacturing and installation of the 2 Fast Position Power Supplies, 10 Equilibrium Field Power Supplies, 1 Toroidal Field Power Supply and matching transformers for the magnet coils of JT60-SA. The power supplies have been tested at full power in factory.
JT60-SA is a Tokamak type fusion machine designed to support the operation of ITER, as part of the upgrade of the existing JT60, the ECH for plasma heating required an upgrade and Jema will manufacture and install the gyrotron power supplies consisting of 1 main power supply, 2 body power supplies, 2 anode power supplies and 3 dummy loads.
Description of the project

Iseult is part of a program dedicated to neuro-imaging. The objective of the MRI superconducting magnet is to study the human brain. This machine will produce a very high magnetic field of 11.75 Tesla.

Jema was awarded the supply of one very high precision power supply to feed the MRI SC magnet.

The challenge is the high precision at low DC output voltage.
Description of the project

ESS Bilbao is an ion linear accelerator to support the Spanish participation in accelerator projects worldwide.

Jema supplied 2 klystron modulators; based on our previous experience with HVPS for JET we developed a new topology based on high voltage high frequency cast resin transformers avoiding the use of oil for HV isolation.
Description of the project

The collaboration agreement between ESS Bilbao and SNS Oak Ridge included the supply of a new topology of klystron modulator which will be intensively tested by the ORNL RF team.

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>ESS Bilbao</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESCRIPTION</td>
<td>Klystron modulator</td>
</tr>
<tr>
<td>COUNTRY</td>
<td>USA</td>
</tr>
</tbody>
</table>

**Main Features**

- 85kVdc, 160A, 14MW peak 9% duty
- 1.8 ms pulse length
- Integrated IGBT at the output for modulation and protection (no crowbar needed)
- HVHF innovative cast resin transformer
- Containerized layout
- Modular solution
- An extra module for redundancy included
- Solid state design
### Description of the project

The collaboration agreement between IFIMED (Valencia, Spain) and CERN (CLIC-project) includes a High-Gradient S-Band RF Test Stand. This technology is crucial for the development, among other applications, of proton and carbon LINAC’s for cancer therapy.

Jema has supplied two solid state klystron modulators including integration of the S-Band klystron and accessories such as 2 ion pumps, 2 solenoid power supplies and 2 heater power supplies.

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>High-Gradient RF Test Stand</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLIENT</td>
<td>IFIMED</td>
</tr>
<tr>
<td>DESCRIPTION</td>
<td>Klystron modulator</td>
</tr>
<tr>
<td>COUNTRY</td>
<td>Spain</td>
</tr>
</tbody>
</table>

#### Main Features
- 150kVdc, 110A, 16.5MW peak power
- 10µs maximum pulse length
- Repetition rate 400Hz
- Solid state technology
Description of the project

ITUR, Ion Torrent of Ultimate Reliability, is a test stand of a high power Ion Source. ITUR will be used to make a comparative between different H- Ion Sources.
**Description of the project**

The Front End Test Stand (FETS) in Rutherford Appleton Laboratory (RAL, UK) is a high energy pulsed proton driver which will be required in future neutron spallation sources. Spain contributes to the project through the Universidad del País Vasco and ESS-Bilbao.

Jema supplied three high precision power Supplies for the magnet coils.
PETRA III

CLIENT
Deutches Elektronen Synchrotron (DESY, GERMANY)

DESCRIPTION
High Precision Magnet Power Supplies

COUNTRY
Germany

Main Features
- Short time accuracy 2ppm/day
- Long-time accuracy 15ppm/year
- Linearity 3ppm
- Temperature coefficient 1ppm/K
- Total accuracy <30ppm

Description of the project

PETRA III is a new high-brilliance synchrotron radiation source. The existing storage ring PETRA will be one of the most brilliant x-ray sources worldwide.

Jema was awarded the design, manufacture and commissioning of 5 different high precision power supplies that is 1 x AC dipole PS: 1330V/755A, 1 x DC dipole PS: 1560V/520A, 2 x quadrupole PS: 210V/650A, 3 x sextupole PS: 85V/200A and 1 x universal PS.
Description of the project

The SPS (Super Proton Synchrotron) machine is used as an injector for the LHC (Large Hadron Collider) project.

Jema supplied 30 true bipolar power supplies according to the specification of CERN (N07 & N08).
Description of the project

The Wendelstein 7-X is the biggest Stellerator nuclear fusion installation in the world. Jema supplied 10 independent switched-mode power supplies for the 10 control coils of the Stellerator.

The equipment has been designed to withstand an electromagnetic field of 50mT (in the picture a factory test with this electromagnetic field)
**PROJECT**

**Gyrotron plasma heating TCV tokamak**

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>CRPP (Centre de Recherches en Physique des Plasmas)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESCRIPTION</td>
<td>HV Anode Modulator Power Supply</td>
</tr>
<tr>
<td>COUNTRY</td>
<td>Switzerland</td>
</tr>
</tbody>
</table>

**Main Features**

- Solid state technology
- Floating output referred to -80kV of the gyrotron cathode potential
- Output voltage -5kV to 30kV
- 1kHz square and sinusoidal modulation
- Fast switching off to -5kV (10μs)
- Pulsed operation (duty cycle of 1%)
- Output voltage stability 0.5%

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**Description of the project**

The TCV is a Tokamak type fusion machine installed at CRPP in Lausanne.

Jema supplied 3 anode modulator power supplies to feed the anode grid of a triode type gyrotron, used for heating purpose at the third harmonic in the TCV Tokamak.

The equipment is capable to discharge 200pF stray capacitance in parallel with the 3MΩ equivalent resistance of the gyrotron.
The TJ-II is a Stellerator experimental fusion machine constructed in Madrid by CIEMAT during the 90’s.

Since the beginning and along the life of the project Jema has been selected to provide the different power supplies for coils and plasma heating devices NBI and ECH.
Description of the project

Tokamak Energy is a privately funded company based in Oxfordshire UK. Tokamak Energy’s experiment ST-40 will be the largest high-field (>2 Tesla) spherical tokamak in the world.

Jema Energy was selected to design, deliver and commissioning the Toroidal Field Power Supply in just 10 months from the contract signature. As the infrastructure doesn’t allow for high power connection the power supply uses ultra-capacitors as energy storage (17MJ).
Description of the project

Tokamak Energy is a privately funded company based in Oxfordshire UK. Tokamak Energy’s experiment ST-40 will be the largest high-field (>2 Tesla) spherical tokamak in the world. Jema Energy was awarded the Solenoid power supplies based on a solution using super capacitors.

Main Features

- +17.1kA -14.5kA
- 1s pulse
- IGBT based solution, with low ripple current
- Energy stored in ultra-capacitors
- Bidirectional Crowbar
- 4 quadrant operation
Description of the project

Tokamak Energy is a privately funded company based in Oxfordshire UK. Tokamak Energy’s experiment ST-40 will be the largest high-field (>2 Tesla) spherical tokamak in the world. Jema Energy was selected to design, deliver and commissioning the BvU Power Supply as the infrastructure doesn’t allow for high power connection the power supply uses ultra-capacitors as energy storage.
PROJECT C-2W

CLIENT Tri Alpha Energy
DESCRIPTION Mirror & Equilibrium Coils PS
COUNTRY USA

Main Features
- Modular power blocks of 1.1kV, 3.6kA
- Maximum configuration 4x4 (4.4kV, 14.4kA)
- Energy stored in film capacitors

Description of the project

Tri Alpha Energy, TAE, is a private funded fusion research company located in the USA. Their Field Reverse Configuration (FRC), has shown very promising results with the C-2U experiment. Jema has been selected for the design, manufacturing, installation and commissioning of 12 PS for Mirror and Equilibrium coils for TAE’s new experiment C-2W. In total 128 power blocks have been delivered to make up the 12 configurable power supplies.
Description of the project

Tri Alpha Energy, TAE, is a private funded fusion research company located in the USA. Their Field Reverse Configuration (FRC), has shown very promising results with the C-2U experiment. Jema was selected for the design, manufacturing, installation and commissioning of 2 Electrode Power Supplies for the C-2W experiment.
Description of the project

Tri Alpha Energy, TAE, is a private funded fusion research company located in the USA. Their Field Reverse Configuration (FRC), has shown very promising results with the C-2U experiment. In 2017 Jema received the order for the design, delivery and commissioning of 8 Neutral Beam Injection HV Power Supplies for the C-2W experiment.
Main Features

- Power rating 660kVA
- Solid state technology IGBT
- 115kV/100A pulse 3.5ms/14Hz
- Stacked Multilevel Modulator

Description of the project

The European Spallation Source (ESS) is a European Research Infrastructure Consortium (ERIC), a multi-disciplinary research facility based on the world’s most powerful neutron source. In 2017 Jema received the order for the manufacturing of 3 + 9 Klystron Modulators.