Innovative VHF generators for challenging plasma processes

Preface

For today’s semiconductor and large area plasma processing applications, the variety of required power levels and frequencies increases tremendously. In addition, each application requires different features. This makes the creation of a generator portfolio capable of covering this broad range of RF requirements very ambitious. In order to overcome this challenge, TRUMPF Hüttinger has developed a variety of generators based on a platform concept using many of the same components. Using smart RF power scaling, this platform allows the creation of a customized and cost-optimized RF generator solution to fulfil customer requirements. As a first step to this approach, TRUMPF Hüttinger offers a 40.68 MHz generator with power scaling starting from 1 kW up to 10 kW (with master/slave capability) in ½ rack and full 19 inch dimensions.

Technology

The generator contains stackable power supplies and a modular control concept. The amplifier incorporates robust LDMOS switch-mode RF technology with internal power compensation. This planar concept allows a space-minimized implementation of the RF stage with the lowest losses possible, allowing for super-compact housing. Based on the RF stage, the generator exhibits state-of-the-art wall-plug efficiencies of > 70 %. This approach allows the realization of RF generators that require only water-cooling, eliminating the need for lifetime limiting fans. The absence of fans also provides the great advantage of silent operation, exceeding today’s semi clean room noise requirements and allowing generator installation at the plasma system.

Features

The novel VHF generators exhibit some unique optional features that enable smoother, more reliable plasma operation and a significant yield improvement:

- **Cable length insensitivity**

Most available RF generators exhibit a 50 Ω output, but with an unintended asymmetric output power characteristic into complex loads (see the pictures below). All TRUMPF Hüttinger generators exhibit a patented CombineLine technology that ensures symmetrical power distribution, enabling generator operation with reproducible rise times for any given cable length.

As an example, the picture below shows a 40.68 MHz generator with an output power of 10 kW, realized in 19 inch 3U housing.

<table>
<thead>
<tr>
<th>Power Level</th>
<th>1 kW</th>
<th>2.5 kW</th>
<th>5 kW</th>
<th>10 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.12 MHz</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>40.68 MHz</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>60 MHz</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>81.36 MHz</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>100 MHz</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

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generating confidence
This furthermore leads to very stable power delivery and a more smooth plasma process, since the reduced plasma fluctuations lead to less power variations. This effect greatly improves the results for sensitive material deposition and etching processes.

### Signal generation

The generator’s internal signal generation is based on an advanced digital modulation scheme. In addition to superfast rise/fall times, this digital signal creation allows various pulse pattern generation, e.g. multi-level pulsing, ramps or plateaus.

Even at high output power levels, the rise time during plasma ignition, and/or between two power levels, is well below 5 ms, thus providing fast and reliable power operation. As an example, the pictures below show ignition (<100 us) and a power level change (< 2 ms) into a capacitively coupled plasma (CCP) for a 40.68 MHz 10 kW generator.

### Auto frequency tuning

Based on digital signal generation, all VHF generators incorporate a patented auto frequency tuning algorithm that operates concurrently, rather than consecutively. The tuning range is ±5 % around the center frequency for all generators (e.g. for 40.68 MHz the range is between 38.64 MHz and 42.71 MHz). The digital signal generation and patented algorithm enable the generator to always find the absolute minima, providing reproducible processing results and the fastest reaction possible on any kind of plasma.

### Accuracy

The accuracy for power delivery becomes more and more important since the layer thicknesses become thinner. All VHF generators exhibit the possibility for a NIST-based calibration that ensures an accuracy of ±1.0 % (±1 W) into 50 Ω. This accuracy can be ensured for the complete power range between lowest (3 W) and highest power level without any additional calibration effort.

### Specifications (e.g. for 10 kW 40.68 MHz)

- Wall plug efficiency > 70 %
- 3 phase wide range input, 200 – 480 VAC ±10 %
- Completely water cooled, no fans
- Compact size, 19” 3U
- Pulse freq 1 Hz – 100 kHz
- Duty cycle 1 – 100 %
- Accuracy ±1.0 % / ±1 W (whichever is larger)
- RF Output LC or customized
- 50 Ω Output – cable length insensitivity
- Available features
  - Arc management
  - Auto frequency tuning (±5 %)
  - Multi-level pulsing
  - Arbitrary pulse shaping
  - A multitude of different interfaces
    - DeviceNet
    - EtherCAT ETG
    - RS232 / RS485

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