### COMPANY PROFILE OF MR – BU FOR POWER QUALITY
FOCUSED ON CUSTOMER BENEFITS

Increasing corporate value in global niches of electrical power engineering while preserving our independence

<table>
<thead>
<tr>
<th>Marketing of proprietary technologies</th>
<th>No transformers without a MR product</th>
<th>Preferred system integrator</th>
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</thead>
<tbody>
<tr>
<td>REINHAUSEN PLASMA</td>
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<tr>
<td>Surface Modification and Powder Coating</td>
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<tr>
<td>REINHAUSEN CAM</td>
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<tr>
<td>Decision Support for Manufacturing Excellence</td>
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<tr>
<td>POWER COMPOSITES</td>
<td></td>
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<tr>
<td>Composite Materials and Insulators</td>
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<td>MESSKO INSTRUMENTS</td>
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<tr>
<td>Equipment Control and Assessment</td>
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<tr>
<td>TRANSFORMER CONTROL</td>
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<tr>
<td>Control of Power Transformers</td>
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<td>POWER QUALITY</td>
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<tr>
<td>Solutions at Grid Nodes</td>
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<td>HIGHVOLT TESTING</td>
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<tr>
<td>Testing and Measurement Technologies</td>
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| Task                               | Products                                                                 | |
|------------------------------------|--------------------------------------------------------------------------|
| Surface Activation for Industrial Processes | ![Surface Activation](image1)     | |
| Functional Coatings by Plasma Technology | ![Plasma Technology](image2) | |
| Integration of Shop Floor Data Models into ERP | ![ERP](image3) | |
| Optimization of Automated Manufacturing Processes | ![Manufacturing Processes](image4) | |
| Mechanical & Electrical Endurance by GFRP | ![GFRP](image5) | |
| Composite Insulators for HV / MV Equipment | ![HV / MV Equipment](image6) | |
| Sensors, Accessories, Oil Analytic Laboratory and Secondary Brands | ![Laboratory](image7) | |
| Process Measuring and Control Technologies for Industry Applications | ![Industry Applications](image8) | |
| Actuators, Electronics and Data Management | ![Data Management](image9) | |
| Transformer Services | ![Transformer Services](image10) | |
| Filters and Reactive Power Compensation | ![Compensation](image11) | |
| Power Flow Control in Distribution Networks | ![Distribution Networks](image12) | |
| Shop Floor Testing Systems for Grid Components | ![Grid Components](image13) | |
| Mobile HV / MV Systems for On-Site Testing | ![On-Site Testing](image14) | |

<table>
<thead>
<tr>
<th>Brand</th>
<th>THE POWER BEHIND POWER.</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td><a href="http://www.reinhausen.com">www.reinhausen.com</a></td>
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</tbody>
</table>
POWER QUALITY
Ensuring reaction-free operation of critical industrial applications; Regulated local distribution stations for stable operation of distribution and industrial networks.
**Integrated consulting approach for complex Power Quality solutions**

- PQ is a solution partner for customers in case of Power Quality Issues (e.g. shutdown of production facilities, harmonics, etc.)

- PQ gives support from the analysis of the problem to the commissioning of the technical installation (compensation plant etc.)

**Advantages for the customer**

- Highest staff competence by long lasting experience in PQ project business – in practice and theory – from simulation, planning, installation and service

- Fullfilment from beginning until project installation (incl. service)

- Not bounded to own product portfolio -> best economical and technical solution for the customer

- Long refernce list by world-wide experience in complex PQ projects (renewable energy parks, offshore platforms, industry installations, public distribution networks…)

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**Power Quality Challenge**

**Evaluation (Measurements)**

**Simulation (Network Study)**

**Project Planning (PQ Installation)**

**System Commission-ing**
Question:
- Will there be an interesting market for Power Quality Flexibility Options or when will it start?
LV AND MV POWER QUALITY SOLUTIONS FOR DISTRIBUTION NETWORKS

Solutions at the Point of Common Coupling (PCC)

**Trends:**
- Change from passive compensation systems to active systems (Active Filters, SVC, STATCOM...)
- Standard Solutions for Voltage Regulation of Distribution Transformers available

- Passive Inhouse Compensation Systems
- Passive Systems with Container
- Passive Systems in Air Insulated Switchgears
- Passive Systems with SKID
- Dynamic Systems: SVC, STATCOM and Active Filters
- Variable Shunt Reactor
- Voltage regulated Distribution Transformer (VRDT)
- Dynamic Systems: Static Var Compensator (SVC)
Application Fields for Power Quality Solutions at the PCC

- Cement Industry
- Paper Industry
- Chemicals Industry
- Renewable Energy (onshore / offshore)
- Steel Industry
- Transport / Automotive /Aviation
- Mining Industry
- Oil & Gas (onshore/offshore)
- Public Distribution Grids
- Power Plants
- Public Distribution Grids
- Power Plants
EXAMPLE 1:
VOLTAGE REGULATED DISTRIBUTION TRANSFORMERS (VRDT)

Medium voltage grid

Substation

Low voltage grid

1 Transformer

3 Voltage regulator

2 On-load-tap-changer

Detached voltage measurement

PV

G

Sensor

Regulator

Actuator

Voltage measurement at the transformer

PV

PV

PV
EXAMPLE 1: GRIDCON® iTAP® - MAKING VOLTAGE REGULATION IN DISTRIBUTION GRIDS REALITY (VRDT)

### Produkt launch
- GRIDCON® iTAP® is presented in 09/2012
- The first transformers with GRIDCON® iTAP® go live

### Market success
- More than 600 transformers with OLTC GRIDCON® iTAP® are operated in distribution grids around the world
- FGH certifies a transformer with GRIDCON® iTAP®
- First DSOs as E.ON Subsidiaries and EWE Netz GmbH defined VRDT as standard solution for voltage regulation

### Upgrade:
- New and improved features make GRIDCON® iTAP® even better

### Add-ons:
- New and improved products complement GRIDCON® iTAP®
EXAMPLE 1: NEW AND IMPROVED FEATURES
MAKE VRDT WITH GRIDCON® ITAP® EVEN BETTER

1. 2nd version: Rated through current of up to 85 A
   VRDT available up to 4.500kVA (24kV)
2. Advanced voltage control algorithms:
   - **Dynamic voltage set point** based on assessment of measured power or current
   - **Remote sensor measurement** voltage control
   - **Holistic grid-wide voltage control** relying on multiple remote sensors
3. Operating mode **without additional losses** from reactors*
4. **MODBUS TCP** support
5. **Extended data points** for IEC 60870-5-104
6. Advanced measurement and logging of power quality data
7. Approved for **alternative insulating liquids**
8. Approved for **outdoor use**

*Reduces number of positions to 5; stops in bridging positions with losses for short period of time; **Motor only, control cabinet needs to be housed
Note: Some features at extra charge
EXAMPLE 2: VARIABLE SHUNT REACTOR FOR PV PARK

CHALLENGE - GRID CODE REQUIREMENTS IN GERMANY

Reactive Power Infeed acc. BDEW MV Grid Code

<table>
<thead>
<tr>
<th>Power range of PV power plant</th>
<th>Voltage range</th>
<th>Requirement at PCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 10 % of the rated power</td>
<td>±10 % of rated voltage $V_N$</td>
<td>less reactive power infeed than 10 % of the contractually agreed active connection power</td>
</tr>
<tr>
<td>10 – 100 % of the rated power</td>
<td>±10 % of rated voltage $V_N$</td>
<td>variable power factor in the range from 0.95cap to 0.95ind</td>
</tr>
</tbody>
</table>

Source: BDEW MV Grid Code

In Germany new requirements for the adjusting range of the reactive power are obligatory since 01.01.2014.

New renewables-based plants in Germany mustn’t be connected to the grid without a certificate which proves the network conformity.
Case Of Application – Large-Scale PV Power Plant

PV power plant
- Voltage level: 20 kV
- Rated power: 8000 kWp
- Connection cable: 22 km / 300 mm² standard cable

VSR
- Voltage level: 20 kV
- Switching principle: OLTC based on reactor principle
- Numbers of OLTC: 2 (series-connected)
- Rated power: 1000 kvar
- Inductive power range: 350 up to 1000 kvar
- Operating positions: 13 (45 up to 65 kvar inductive)
EXAMPLE 2: VARIABLE SHUNT REACTOR FOR PV PARK
TECHNICAL REALISATION OF THE VARIABLE SHUNT REACTOR

Technical Data and Layout

- standard three-phase oil reactor
- variable inductance due to tappings by OLTC (GRIDCON® iTAP®)
- operating positions: 9 per OLTC (max. 13 with 2 OLTCs)
- inductive power range limits: ca. 35 % to 100 %
- implementation in concrete or metal-enclosed station

concrete station with VSR (control and protection equipment inside)

OLTCs top side of the VSR

VSR in construction status
EXAMPLE 2: VARIABLE SHUNT REACTOR FOR PV PARK

RESULTS

Manual Operation Of Shunt Reactor (night time)

Stepwise Change of inductive Power at PV busbar leads to

- stepwise capacitive power compensation at PCC
- prevention of voltage increase at PV busbar
EXAMPLE 2: VARIABLE SHUNT REACTOR FOR PV PARK

RESULTS

Automatic Operation Of Shunt Reactor (typical summer day)

avoidance of capacitive power flow at PCC

<table>
<thead>
<tr>
<th>Time</th>
<th>Active Power [MW]</th>
<th>Reactive Power [Mvar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00</td>
<td>3</td>
<td>-0.5</td>
</tr>
<tr>
<td>4:00</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>8:00</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>12:00</td>
<td>2</td>
<td>-0.5</td>
</tr>
<tr>
<td>16:00</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20:00</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>24:00</td>
<td>3</td>
<td>-0.5</td>
</tr>
</tbody>
</table>

P at PCC | Q at PCC (with Shunt) | Q at PCC (without Shunt) | Q of Shunt
EXAMPLE 2: VARIABLE SHUNT REACTOR FOR PV PARK

RESULTS

Automatic Operation Of Shunt Reactor (typical summer day)

voltage decrease of 1.5 % \( \triangleq \) \( \sim \) 300 V

![Graph showing time series for Active Power and Voltage with and without Shunt](attachment:graph.png)
EXAMPLE 3: ACTIVE FILTER @ MUNICH AIRPORT
OPTIMIZING THD WITH GRIDCON® ACF

Munich Airport

Aim:
- Installations to supply aircrafts with pre-conditioned air before take-off cause non-linear current
- Without filters, the current of the air conditioning units have a total harmonic distortion (THD) of 42%
- Increased harmonics levels cannot be tolerated in an airport environment

Power Quality Challenge:
- Need for decentralized and efficient filtering concept
- Strict guidelines regarding service and quality must be met

Shape of grid current without filtering
GRIDCON® ACF
Modular Active Filter

- Touch panel 7"
- Control-Computer CCU
- IGBT-Units IPU 125 A
- Measuring & I/O Unit MIO
- Control section with DC-supply
- Cabinet with cable connection
GRIDCON® ACF compact
Modular Active Filter 4-wire

- Touch panel 7“
- Control-Computer CCU
- IGBT-Units IPU 60 A
- Measuring & I/O Unit MIO
- Control section with DC-supply
- Cabinet with cable connection
EXAMPLE 3: ACTIVE FILTER @ MUNICH AIRPORT
OPTIMIZING THD WITH GRIDCON® ACF

Munich Airport

- MR is supplying 64 active filters for 4-wire connection
- GRIDCON® ACF systems are used for broadband harmonics filtering -> THD Reduction
- The majority of filters is installed in outdoor cabinets
- Special attention was paid to a thought-through safety and service concept, which was to our benefit
- Besides, MR-PQ is taking of part of the project management as this was part of the tender
EXAMPLE 3: ACTIVE FILTER @ MUNICH AIRPORT
OPTIMIZING THD WITH GRIDCON® ACF

Munich Airport:

Result:

- The total harmonic distortion (THD) caused by unit for pre-conditioned air supply was reduced from 42% to less than 5% in a pilot installation.

Shape of grid current and voltage with ACF in operation.