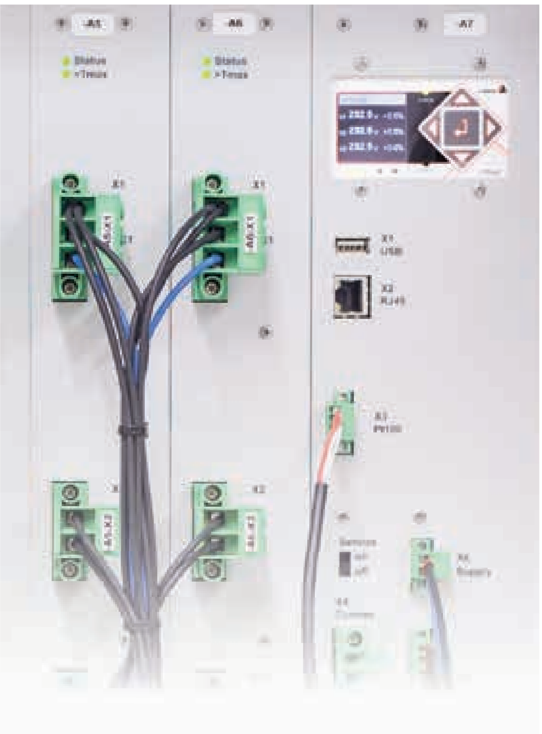
We take care of it.

LVRSys™

It´s all about the right voltage.



- Low voltage regulation in local and industrial grids from 7.5 kVA up to 3150 kVA
- Phase independent regulation (voltage balancing)
- Regulation ranges from ± 6 % up to ± 24 % of the nominal voltage
- Outdoor, indoor or pole mount installation
- Single- or three-phase regulation
- Adjustable response time of the controller < 30 ms
- Integration in customer installations (e. g. regulation of self-consumption)
- Grid configurations TT / TNC-C / TN-S / IT
- Line or direct transformer regulator

LVRSys™ for Power Utilities

Low Voltage Regulation System

EEG and BMWi – Distribution grid study 2014

In Germany climate and environmental protection is characterized by a high degree of political and public interest. For this reason a German Law supporting the production of renewable electricity (EEG) was introduced. This law is used to promote and develop technologies that generate power from renewable energy sources.

The EEG apportionment has increased continuously and explosively in recent years. In 2014 the tax on alternative energies was € 6.24 ct/kWh. In 2015 the tax stabilized at the very high level of € 6.17 ct/kWh. The massive economic pressures led EEG to bring a significant subsidy reduction in 2014. However, the targets are fixed now. The share of renewable energies as part of gross electricity consumption has to rise up to 45 % by 2025 and to 80 % by 2050. To achieve this purpose this means an average expansion of 2.5 GW photovoltaic and 2.5 GW of onshore wind yearly. As such, the German energy supply found itself at the point of a significant change. The transport and distribution grid, which has been built over a hundred years, was renovated in just a few decades. Studies such as the BMWi (the distribution grid study) provided an overview of the necessary grid expansion requirements and showed alternatives to reduce classic grid expansion predicted investments via intelligent equipment and solutions.

According to such studies, in the low voltage levels, the use of new technologies can almost completely compensate the grid expansion.

A cost-effective solution for this challenge is the **LVRSys™**, an already marketed, proven, robust and service-friendly device, which not only solves voltage problems but also reduces network losses.

Cost-effective alternatives for grid expansion ensure acceptance of energy transition

The total cost of energy transition is up to € 150 billion by 2015. With a cost share of € 125 billion the EEG total allocation was by far the biggest cost driver. The total costs of the new energy age will probably increase to an estimated value of € 560 billion by 2025. Up to € 80 billion will be spent on grid expansion. The acceptance of the energy transition is at stake because of the enormous cost factor. In addition, the grid expansion is often incomprehensible. Energy suppliers, grid operators and the Federal Network Agency are now under the obligation to not risk the century's project, the energy transition.

Previous planning of low voltage grids

New low voltage grids were developed according to plan and built criteria such as:

- Maximum grid load
- Stations at the load center
- Thermal continuous load and voltage maintenance
- Maximum cable load approx. 50 %
- Maximum station load approx. 2/3

Frequently 4 x 150 mm² cables have been used since they are considered short-circuit proof and have hardly taken a significant cost weight in relation to the total cost of civil engineering work. As a result of these planning guides most low voltage grids were oversized in consideration to current carrying capacity.

Voltage maintenance in low voltage grids

According to the European standard EN 50160, in the low voltage grid, a voltage tolerance of ± 10 % versus the nominal voltage is permisible. According to the low voltage directive VDE-AR-N 4105 decentralized generators are allowed to increase the voltage by a maximum of 3 %. An increase of the voltage by 3 % is achieved very quickly with a low voltage cable and this is usually the main criteria for the connection of new, decentralized generation units. For a standard 4 x 150 mm² aluminum cable a voltage boost of 3 % is already reached at a length of 230 m. However the current carrying capacity of the cable would only reach 50 %. Ten years ago few distribution grid operators reported problems with the voltage maintenance in the low voltage grid. Through the installation of PV-systems there were mainly violations to the upper tolerance band as defined by the EN 50160. In the future an increased use of heat pumps and electro-mobility applications is forseen, so it can be expected that the voltage band will be exploited or rather violated in both upper and lower directions.

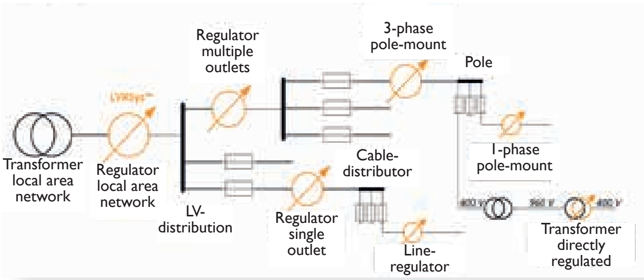
Electromobility

In Germany the 2015 discovered diesel-engines exhaust gas affair raised the issue of electro mobility to a new level. The Federal Government plans to have 1 million electric vehicles on the roads by 2020. By 2030 this number should be increased to 6 million. The total emitted emissions from electrical energy production and mobility can only be reduced if the electrical power generation is almost completely converted to renewable energy. Initial studies described the effects of e-vehicles on the transmission network by 2030 as almost unnoticeable. Unfortunately the reality looks quite different and hence the distribution networks will be thereby burdened. As a result grid operators once againg after the boom of photovoltaics are forced to reinforce the grid. Over 90 % of the charging of e-vehicles will be at home using 32 A or 16 A outlets. This can lead to voltage problems for rural grids. The **LVRSys™**, encapsulated into a controllable street cabinet is designed to provide relief for such situations.

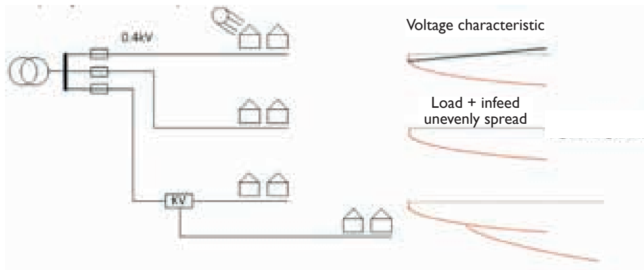
Grid stability and reliability through line regulator

The low voltage regulation system is praised by grid operators on the fact that it is simple to assemble and dismantle. In addition, all three phases are controlled independently, which leads to an improvement in the grid voltage asymmetry. Since the voltage maintenance problem is not the same in all low voltage grids, the **LVRSys™** network operator can resort to several performance classes. Applications are ranging from the controllable street cabinet to the controller of an entire local area grid.

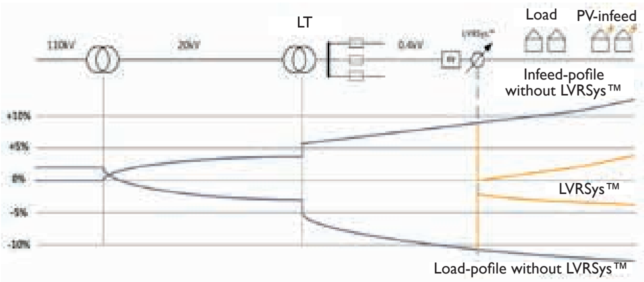
If the feeders and loads are unevenly distributed the voltage spreads. In many cases the power reference and the power delivery at the bus bar are nearly equal, therefore a central control directly at the bus bar cannot generate suitable control. External voltage measurement values would have to be used by the system which is done by complex communication lines.



LVRSys™ - application sites in a low voltage grid

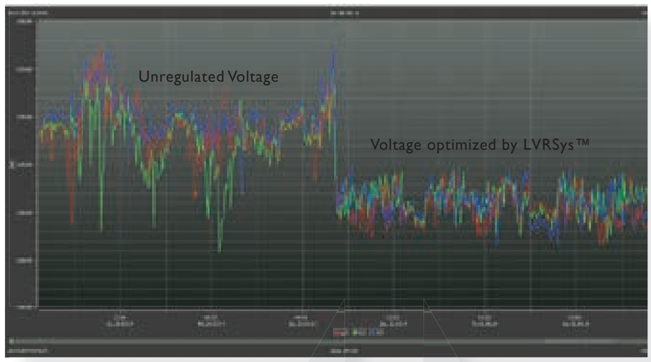


Voltage spread in a low voltage grid

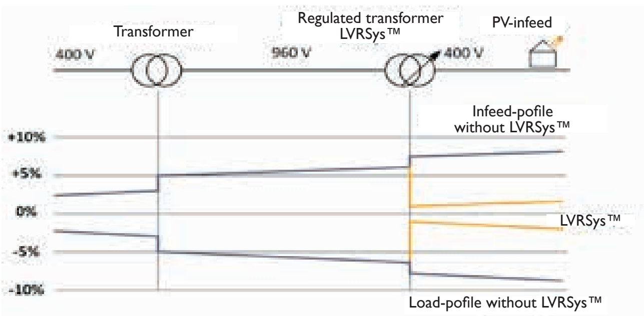


LVRSys™ - response model line regulator

If the short-circuit power to the distant consumers is too low, the controller is implemented as a direct transformer regulator.



Unregulated voltage compared to regulated voltage by LVRSys™



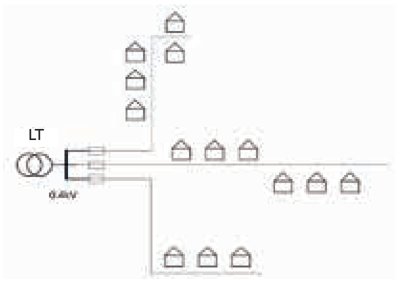
LVRSys™ - response model line regulator implemented as direct transformer regulator

It is much more effective to change the voltage level of the local grid transformer and to use the **LVRSys™** voltage regulator system. For example, the bus bar voltage can be set to 410 Vac, which counteracts the voltage drop of the loads. The feeder equipped with a low voltage regulation system will ensure optimal voltage ratios.

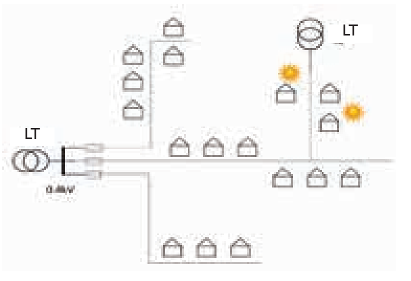
Plan with foresight (economic efficiency)

The regulation systems can generally be used for more than 30 years. Cables and transformers can even be used for over 40 years. The most economical approach would be to be able to accurately estimate the conditions in the low voltage grid over these periods. However this is not possible. Self-assessments over a period of 10 years do not even affect the state of future grids. It is therefore necessary to use flexible operating means. Low voltage regulation systems help to delay grid expansion until there is no longer any alternative to the installation of new transformers and cables. Until the grids are at this point, the low voltage regulation system could shift the expansion by years or decades. Therefore a grid expansion can then be designed efficiently. It is imperative to avoid grid expansion due to voltage stability problems.

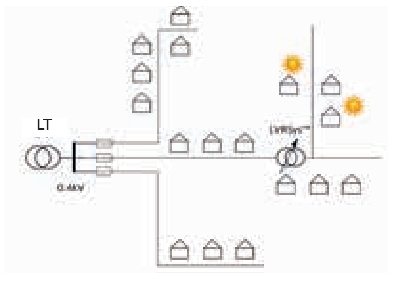
An example of this is a low voltage grid of the simplest type. Figure 1 shows the expansion of the low voltage grid in 2017. By 2020 partial PV-systems are integrated and cause local voltage problems. Measure A stabilizes the voltage by means of grid expansion. Measure B uses an active regulation system. The voltages were stabilized by both measures. When by 2025 further PV systems were installed elsewhere, local voltage problems occured. In addition the local area grid is operated at the operating resource limit hence a network expansion is therefore indispensable. In both variants a local grid substation is now installed. For Measure B the controllers are removed by intermeshing, hence they can be used to avoid misplaced investments.
Line regulators are mobile, thus grid hot spots can flexibly be served with a reasonable count of units.



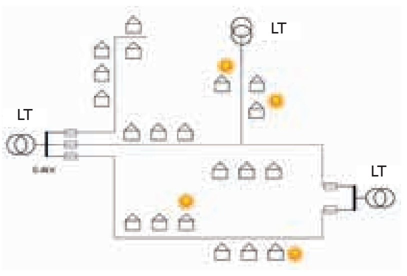
E.g. low voltage grid 2017



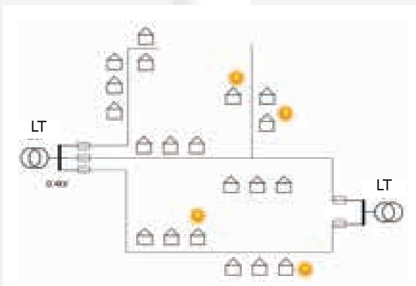
Low voltage grid A 2020



Low voltage grid B 2020



Low voltage grid A 2025



Low voltage grid B 2025

LVRSys™ flexible and robust for any application

Robust
- Over 20 billion of switches
- Short circuit proof up to 50 kA
- High resistance to overloads, direct and indirect lightning strikes
- Overload capable (like NH-fuse)

Reliable and economical
- High efficiency
- Passive cooling even in direct sunlight
- Operating ambient temperature: - 40 °C to + 45 °C
- Electronic humidity-proof housing in the internal control cabinet

Intuitive and secure
- Cable distribution cabinet installations
- Customized connection via NH-switch disconnectors
- In and out of operation via NH-switch disconnectors or automatic circuit breakers
- Fully encapsulated system for maximum contact protection
- Bypass option as a standard

Easy
- Data export via USB stick (e.g. in MS-Excel format)
- Firmware update via USB stick or remote access
- Common communication interfaces Modbus TCP, IEC 60870-5-104
- Display drag indicator

Grid compatible
- No grid interference (i.e. does not cause flicker or harmonics)
- Balancing the voltages by means of phase-independent control
- Existing fuse concept can be retained
- Interruption-free voltage supply guaranteed

Flexible and fast
- Adjustable response time of the regulator (e.g. from 30 ms to 100 s)
- Adaption of the regulation to different applications
- Load-dependent regulation without additional communication
- Independent tolerance bands for dynamic and static control

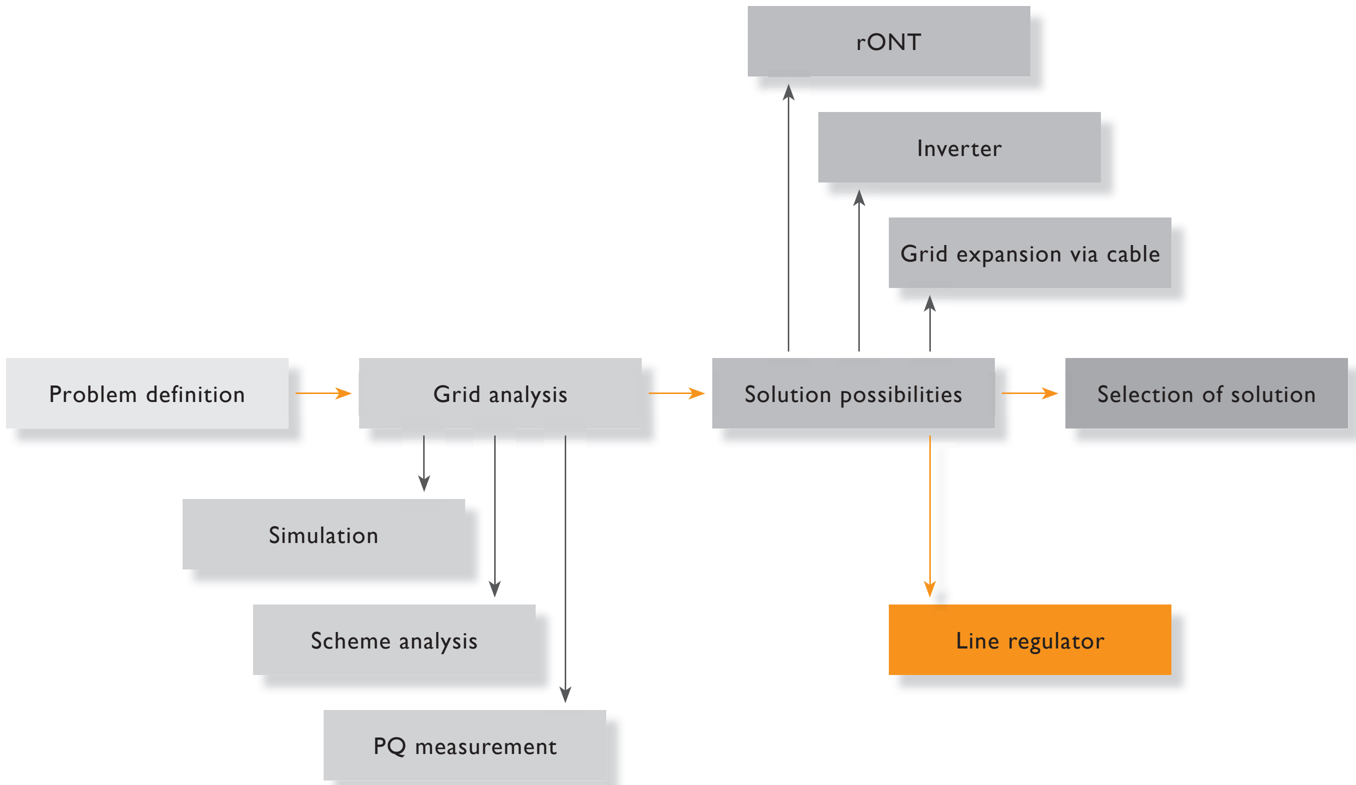
Customized encapsulation designs

The low voltage regulation systems **LVRSys™** are built in a modular fashion. The surrounding housing can be chosen freely. The integration of regulation systems can take place in concrete distribution cabinets as well as in GRP distribution cabinets. Especially in Switzerland low voltage regulation systems are often integrated into concrete distribution cabinets. A. Eberle supplies the transformer block and the control unit in an IP66 housing. German grid operators mainly use GRP cabinets to distribute low voltage. The low voltage regulation system **LVRSys™** can be easily integrated in a variety of enclosures.

Plug & Play – simplest installation and maintenance

The low voltage regulation systems are supplied with concrete base for outdoor applications. For the interior corresponding steel sockets are available, too. The connection of the low voltage cables is via frame clamps up to 240 mm².

Concrete distribution cabinet



Instructions for the use of the low voltage regulation system for grid operators

If the problem and the grid configuration are known, a line regulator can only be used technically optimized and economically efficient. The issue often arises from the fact that a customer files a complaint due to the wrong behavior of inverters or consumer devices. The procedure for this is described in the diagram above.

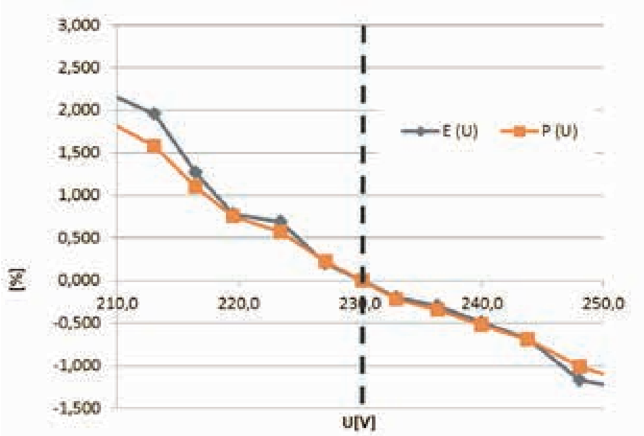
In order to narrow it down, a first glance at the grid configuration is sufficient. Here one can quickly see whether cables or transformer stations are operating at their limits. Simulations can help to look at the entire grid to examine the impact of the locally reported problem on the whole grid. If the problems are not based on the 50 Hz frequency, a Power Quality (PQ) measurement is indispensable (Power Quality compliant with EN 50160). PQ measurements are used to determine whether the disturbances are not caused by higher-frequency voltages.

If the causes are in the voltage maintenance, the grid operator can choose from several possibilities:

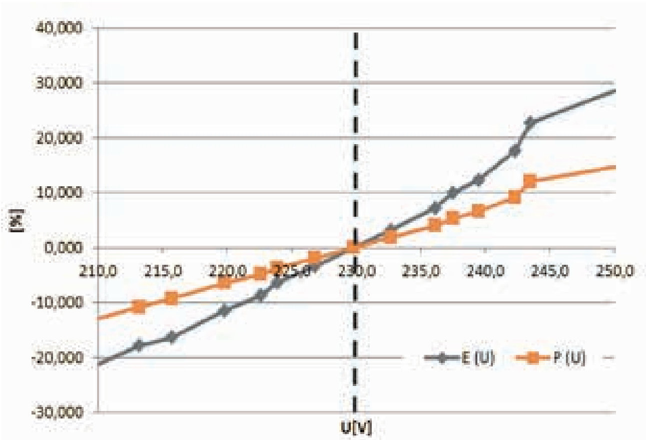
- Grid expansion via cable:
  Only useful if operating equipment is operated at the limits.
- Controllable local power transformer rONT:
  Useful when the medium voltage fluctuates strongly.
- Line regulator:
  Useful for local voltage maintenance problems in the low voltage grid when the operating equipment is loaded up to about 80 %.

LVRSys™ for industry grids (voltage stabilization)

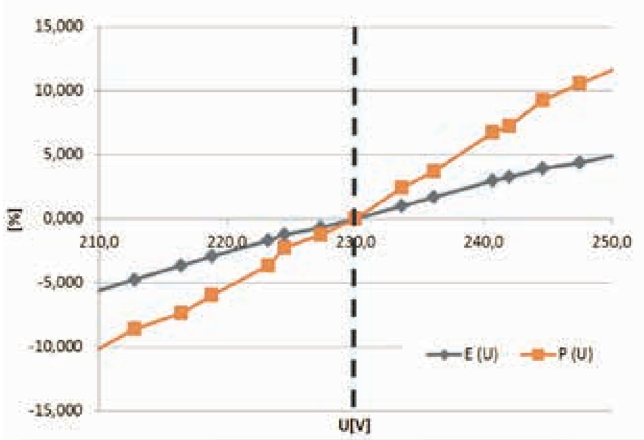
EN 50160 describes, among other things, the voltage band in which the mains voltage must be. The tolerance limits are ± 10 % out of the nominal voltage Un (400 Vac). This corresponds to a permissible voltage band around Un of 80 Vac. Machines, drives and lighting devices are operated most efficiently when the applied voltage is at the operating point. As a rule, the optimum operating point is the nominal voltage of the grid. Outside the operating point, the efficiency and the lifetime of the equipment are reduced. Particularly lighting devices such as the LEDs lose their operating lifetime rapidly with increasing voltage.



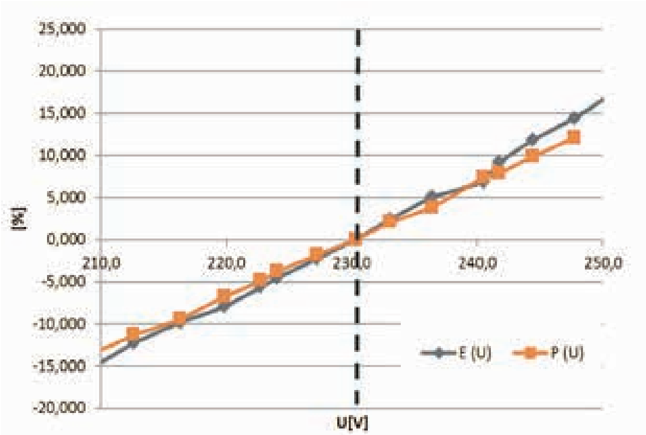
Fluorescent lamp with ECG: Absorbed effective power vs. delivered illumination



Light bulb: Absorbed effective power vs. delivered illumination



LED: Absorbed effective power vs. delivered illumination



Discharge lamp with ECG: Absorbed effective power vs. delivered illumination

LVRSys™ for the integration of energy generation plants into the high voltage grid

Gridcode

The grid and system rules of the transmission grid operators, also called grid codes or transmission codes, serve as requirements for generating plants connected to the high and higher voltage grid. In Germany the regulations VDE-AR-N 4120 is used. Grid codes are applied globally. The system stability is at the forefront.

VDE-AR-N 4120

The VDE-AR-N 4120 describes the technical conditions for the connection and operation of customer systems to the high voltage grid (TAB high voltage). The application rules explain conditions for the mains connection, such as flicker and harmonic levels or reactive power behavior.
Special rules apply to generating plants, which have a net effect. In order to comply with these requirements, the manufacturer is allowed to use additional equipment.
This must be taken into account during operation as well as during the acquisition of the system certificates.

Dynamic grid support

The purpose of the dynamic grid support is to prevent unwanted disconnection of generation power and thus a threat to grid stability. A generating plant shall not disconnect from the mains at:

- 1,30 Un for 100 ms
- 1,25 Un for 20 s
- 1,15 Un for 60 s
- 0,80 Un for 60 s

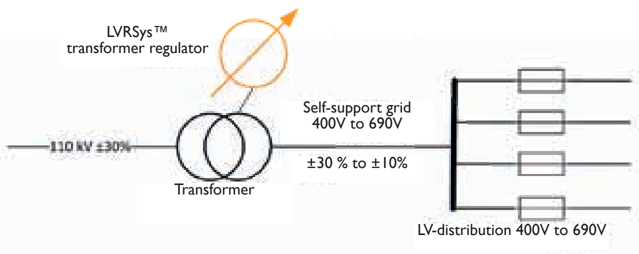
Many components in the generating plant(s) are not designed for long-term overloads.

Essential requirements of voltage stability in quasi-stationary operation (47.5 Hz to 51.5 Hz)

Generating plants must not be disconnected from the mains in the range of 96 kV to 123 kV. This corresponds to an extended voltage range from UN - 13 % to + 12 %. Voltage gradients < 5 % UN/min are regarded as quasi-stationary. In the case of a jump of 10 % the generating unit must not disconnect from the grid, if the generating plant was previously in a stationary state.

Low voltage regulation system LVRSys™

The **LVRSys™** regulates overloads within 15 to 25 ms and improves the static voltage maintenance within the generating plant. The string regulation system allows the certification according to VDE-AR-N 4120. The system can be used in 400 Vac as well as at 690 Vac three phase grids. By virtue of the compact design it can be easily integrated into customer-oriented control cabinets. The system can be understood as a backpack for self-supporting transformers. The control takes place directly at the transformer (controllable local power transformer). However, the control speed through the thyristor technology, which is employed only at step switching time, is significantly faster.



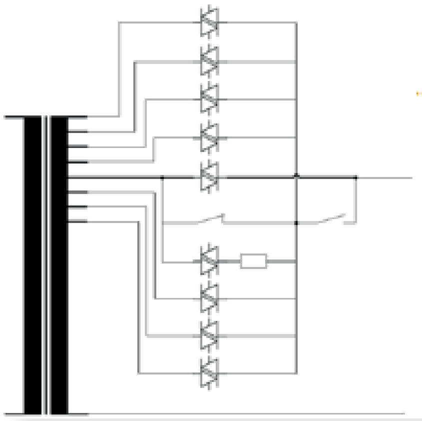
LVRSys™ *used directly at the transformer*

Benefits:

- Integration into customer-specific control cabinets
- Reaction time smaller than 25 ms
- Grid level 400 Vac & 690 Vac
- Version as a line regulator without self-supporting transformer
- Version as a controllable transformer with thyristor technology

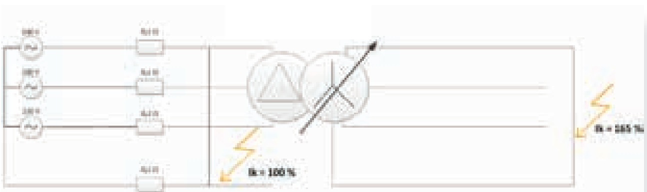
LVRSys™ as a transformer regulator

The principle of operation is the same as that of a transformer and a positioner in the substation. The transformer is a standardized Dy transformer with additional winding taps on the low voltage side. By dynamically selecting the taps the voltage is regulated and asymmetries are additionally compensated.



LVRSys™ as transformer regulator: 1-phase schematic diagram

In long power lines the triggering conditions for fuses in the case of a single-pole short circuit can no longer be met. When a regulated transformer is used the short circuit rating increases approximately by 65 % for a single-pole fault.



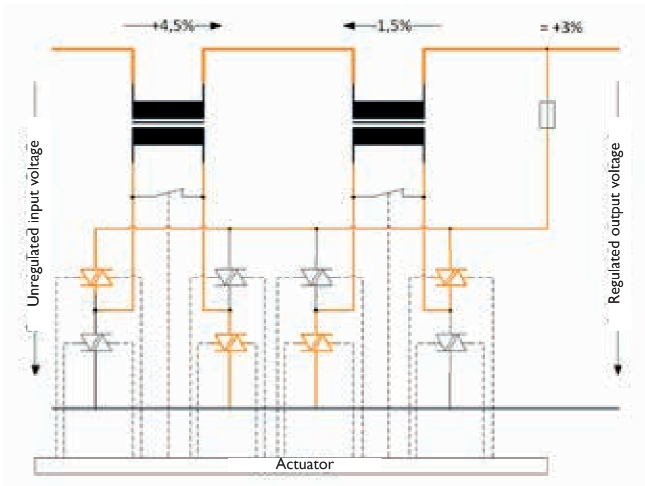
LVRSys™ as transformer regulator

LVRSys™ as a line regulator

The regulation principle of the **LVRSys™** is based on a voltage line regulator. Enabling and disabling two transformers with the selected ratio allows for example regulation of the output voltage in 1,5 % / 2,0 % / 2,5% steps. The maximum standard control range is 6 % / 8 % / 10 %.

The control signal of the thyristors is generated by driver circuits, which intelligently switch on the thyristors. By taking into account the magnetic flux in the transformers the transformers can be switched without voltage dips, current surges and without generating harmonics. All **LVRSys™** can be fused with standard LV-fuses gG. The systems are short circuit-proof and can withstand impulse currents of 50 kA.

All line regulators are protected against direct and indirect lightning strikes as well as switching transients through protection modules.



LVRSys™ as line regulator: 1-phase schematic diagram

LVRSys™ performance characteristics

Grid impedance: The regulator measures the output voltage and scales when the voltage tolerance bands are exceeded or undershot. If the grid impedance is additionally parameterized, a new voltage control value is formed. By taking the measured grid current and the adjusted grid impedance into account, the voltage value in the grid output can be precisely calculated. As such, the regulation can thereby be optimized without communication devices.

Bypass: Each system has a manual bypass switch with integrated LV-fuses. The systems therefore offer the possibility of performing voltage-free service. For example, for applications only used in summer, by activating the bypass, the loss of power during the winter can be completely avoided.

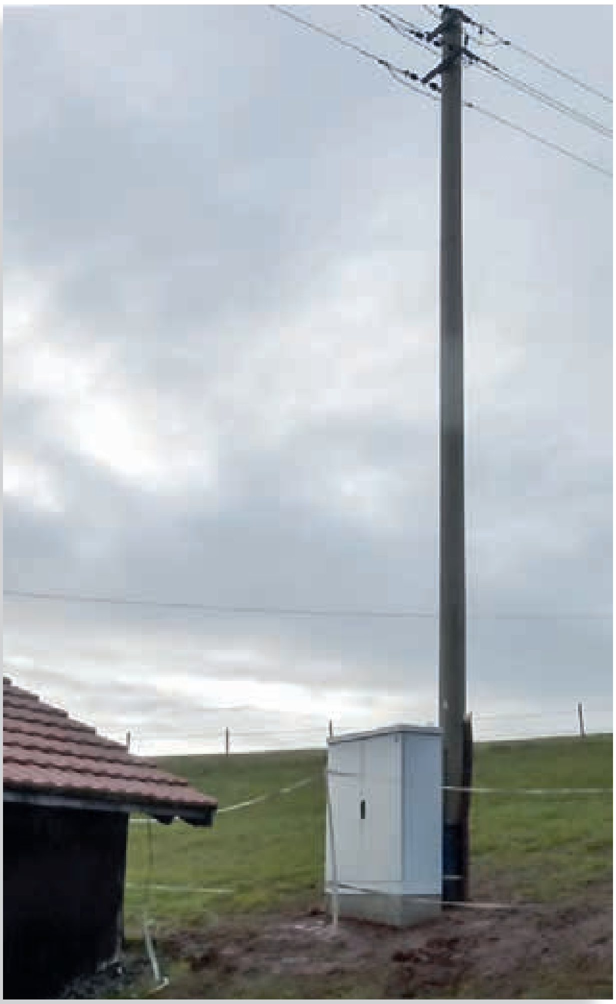

a-eberle


MAIN
SWITCH


A1-6
A7
Status
>Tmax
X1
X1
USB
X2
RJ45
X3
Pt100
X2
X5
Supply

Application examples network operators

Gerhard Trefzer
Energiedienst Netze GmbH Betrieb
Schildgasse 20
79618 Rheinfelden



What was the problem?
Customer complaint: In the case of a PV system installed in 2004, inverter faults suddenly occurred due to mains voltage faults.

What solutions did you consider?
Before considering a solution, a series of steps were taken before the measure was derived:

- Analyze the supply situation
- Measurements in the local area network and house connection box customer connection
- Analysis
- Step
- Re-measurement

*How was the installation of the **LVRSys™**?*
Similar with a cable distribution cabinet.

How ist the operating concept?
Easy to understand.

*Does the **LVRSys™** solve the problem?*
The problem of voltage maintenance has been solved. No customer complaints have been reported since the system installation.

Would you re-use a line regulator with a similar problem?
Yes, ED Netze in the case of a similar problem always will consider the **LVRSys™** line regulator.

Bertrand Houriet
Engineer Smart Grid
Smart Grid Engineering
Dr. Schneider-Strasse 14
CH-2560 Nidau

What was the problem?

Rural grid with an existing PV system (12 kW) on a transformer outlet. Technical connection for an additional PV system (41 kW) on the same outlet. Integration without measures is not possible (voltage boosting at the new and the existing PV system > 3 %, no overloading in the grid).

What solutions did you consider?

Two solutions were considered: Once the conventional grid reinforcement with new cables to some 400 m, so that the voltage boost remains < 3 %. At the same time, the use of a single line regulator was tested alongside an existing distribution cabinet. The single line regulator will compensate both feeders.

*How was the installation of the **LVRSys™**?*

The single line regulator can be integrated into the grid like a somewhat larger distribution cabinet. It should be used especially when connecting the mains cable and the transformer. The BKW fitters can now install and connect the system itself (based on the assembly instructions). The device provides stability for the system and facilitates the connection work.

How ist the operating concept?

The single line regulators run autonomously. They are always assigned same parameters during commissioning. The regulators are monitored via IEC-104 or via SMS (control center).

*Does the **LVRSys™** solve the problem?*

The single line regulator allows decoupling of the voltage between the input and output sides. This reduces the voltage boost in the event of a high feed and a low load. However the short-circuit power in the grid is not increased with the single line regulator (compared to a solution with cable reinforcement). Therefore the switch-off conditions in the whole network should be checked.

Would you re-use a line regulator with a similar problem?

If all the criteria for the single line regulator are fulfilled (integration, costs, switch-off conditions) we would solve such problems further.

Joris Bauweraerts
Elia Engineering
Leon Monnoyerkaai - Quai Léon Monnoyer, 3
B - 1000 Brussel-Bruxelles

What was the problem?

Elia has an auxiliary transformer on the tertiary 36 kV winding of the autotransformer 380/150 kV with provides 3 x 230 Vac or 400/230 Vac+N for the auxiliary services in the substation. Fluctuations on the 380 kV grid will also generate fluctuations on the 3 x 230 Vac or 400/230 Vac+N power supply. These fluctuations are in some substations quite important and damage the equipment.

What solutions did you consider?

We analyzed ABB´s line regulator as well.

How was the installation of the ***LVRSys™****?*

The installation on-site went very well. There were/are some small problems, but A. Eberle is open to discuss them and to find a solution together.

Does the ***LVRSys™*** *solve the problem?*

Measurements and analysis during the coming will tell us whether the problem has been solved or not. Too early at this moment to make an evaluation.

Would you re-use a line regulator with a similar problem?

It depends on the evaluation – see question above.

Achim Jung
Westnetz GmbH
Regionalzentrum Sieg, Grundsatz-/
Ausführungsplanung / Dokumentation
Lindenstraße 20
57334 Bad Laasphe

What was the problem?
Increasing voltage in the low voltage grid caused by PV-systems.

What solutions did you consider?
Cross-sectional elevation of the low voltage grid.

How was the installation of the ***LVRSys™****?*
There were no problems with the installation. Thanks again to A. Eberle for the excellent project support and a very pleasant and trusting communication.

How ist the operating concept?
The instruction manual is clear and comprehensible but it is necessary. The trouble free operation of the **LVRSys™** makes the switching frequency very low.

Does the ***LVRSys™*** *solve the problem?*
Yes!

Would you re-use a line regulator with a similar problem?
Yes, we have already done that. We used a 50 kVA regulator for voltage stabilization in a forestry application, on an approximately 2000 m long line spur.

Bernhard Wittenberg
Technik Innovation (TI)
Netze BW GmbH
Schelmenwasenstraße 15
70567 Stuttgart

What was the problem?
Voltage overshoots EN 50160 due to PV systems at the stranded end.

What solutions did you consider?
Conventional grid expansion or the intelligent solution (line regulator).

How was the installation of the ***LVRSys™****?*
No difficulties.

How ist the operating concept?
Understandable.

Does the ***LVRSys™*** *solve the problem?*
The voltage maintenance problem has been solved – however it turned out that there was also a flicker problem on site. Since after some time it came to customer complaints we were forced to do a conventional grid expansion (new substation). As a result we took the regulator away and searched for a new location where we installed it.

Would you re-use a line regulator with a similar problem?
Yes, only in advance is examined whether other PQ problems (flicker or harmonic levels) are present – when other problems are present conventional grid expansion is necessary.
W

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