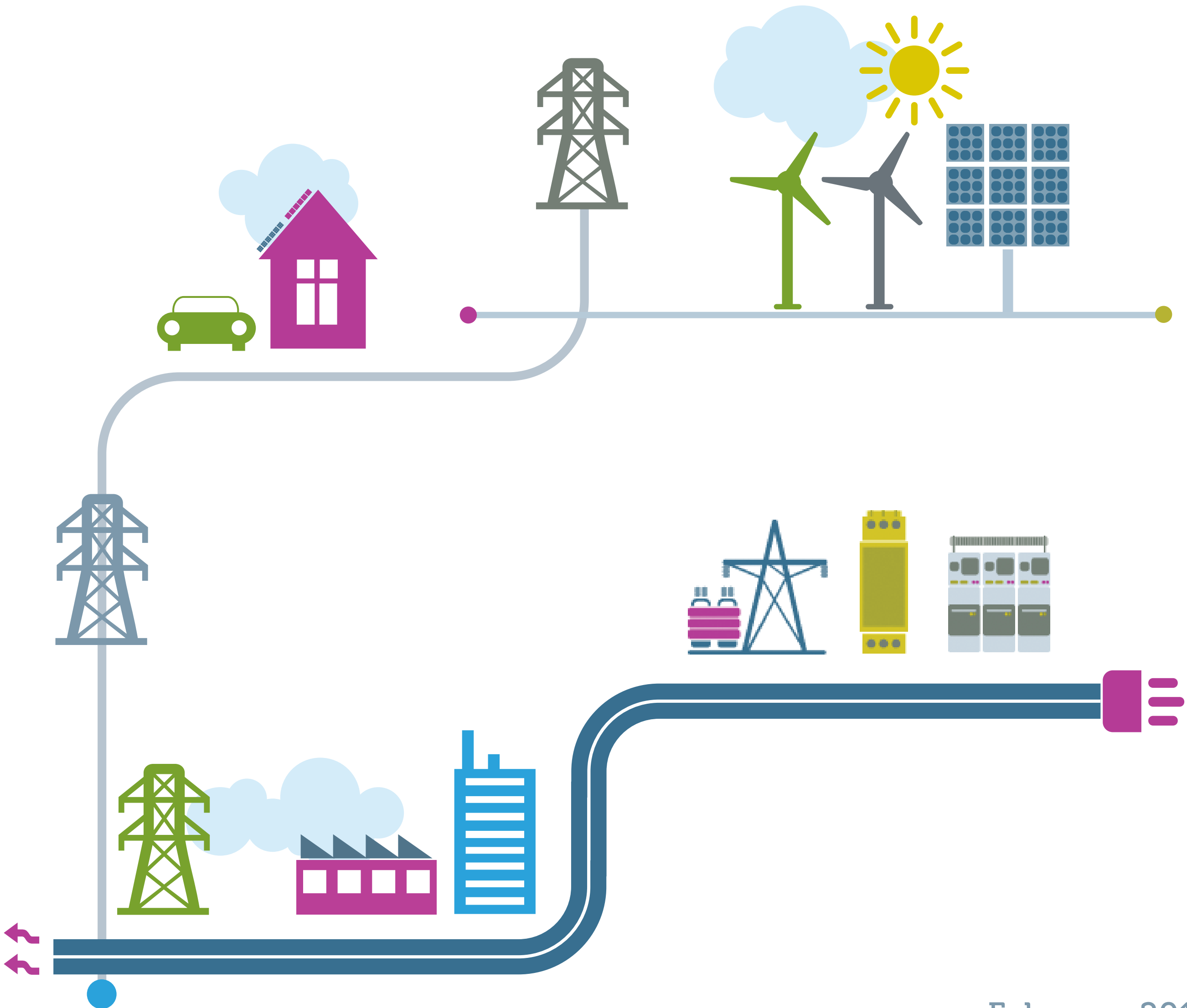
Bringing
power to life.

BEAMA NETWORKS – VOLTAGE REGULATING DISTRIBUTION TRANSFORMERS (2019)



February 2019

ABOUT BEAMA

BEAMA represents manufacturers of electrical infrastructure products and systems from transmission through distribution to the environmental systems and services in the built environment, work with over 200 members ranging from SMEs to large multinationals.

We work with our members to ensure their interests are well represented in the relevant political, regulatory and standardisation issues at UK, EU & international levels.

BEAMA member products providing a sustainable, safe, efficient and secure UK electrical system. We support our members in ensuring that the UK has a strong electrotechnical industry which is recognised as an essential part of modern society and brings invaluable economic, social and environmental benefits.

Our Networks Sector is made up of members with interests in network products, transformers, switchgear, communications, automation, relays, smart grid, and related safety and energy supply and control technology. As part of the networks section of BEAMA, our aim is to explore and develop opportunities, provide technical services and to foster sustainable growth in new markets.

COMPANIES INVOLVED IN THE PREPARATION OF THIS GUIDE

This paper was produced in coordination with the BEAMA Principal Products Section which has membership from the following organisations:

ABB Limited
3100 Daresbury Park, Daresbury
Warrington, Cheshire WA4 4BT

www.new.abb.com/uk/about

Fundamentals
Unit 2 Hillmead Enterprise Park
Marshall Road, Swindon, Wiltshire SN5 5FZ

www.fundamentalsltd.co.uk/

Acrastyle
North Lonsdale Road, Ulverston
Cumbria LA12 9DP

www.acrastyle.co.uk/

GE
St Leonards Building, Harry Kerr Drive
Stafford ST16 1WT

www.ge.com/uk/

Bowers Electricals Ltd
Heanor Gate Road, Heanor
Derbyshire DE75 7GX

https://www.bowerselec.co.uk/

Hawker Siddeley Switchgear
Unit 3 Blackwood Business Park
Newport Road, Blackwood
South Wales NP12 2XH

www.hss-ltd.com/

Brush Transformers
Falcon Works, Nottingham Road
Loughborough, Leicestershire LE11 1EX

www.brush.eu/transformers

Long Controls
Burtonhead Road, St. Helens
Merseyside WA9 5DS

https://longcontrols.com/

Lucy Electric
Howland Road, Thame, Oxon OX9 3UJ
www.lucyelectric.com/en/

Siemens
Sir William Siemens Square, Frimley
Camberley, Surrey GU16 8QD
https://www.new.siemens.com/uk/en.html

Ormazabal
Burtonhead Road, St Helens, Merseyside WA9 5DS
www.ormazabal.com/en

Slaters Electrical
Scotswood Bridge Works
Tollbridge Road, Blaydon, Tyne & Wear
NE21 5TE
https://www.slaters-electricals.com/

PBSI Group
Belle Vue Works, Boundary Street,
Manchester M12 5NG
www.pbsigroup.com/

Wilson Power Solutions
Westland Works, Westland Square
Leeds LS11 5SS
www.wilsonpowersolutions.co.uk/

Schneider
2nd Floor, 80 Victoria Street
London SW1E 5JL
www.schneider-electric.co.uk/en/

Winder Power
Grangefield House, Richardshaw Road
Pudsey, Leeds LS28 6QS
https://www.winderpower.co.uk/

BEAMA and its members would like to extend sincere thanks to MR and BTRAC for their contributions to this report and for their permission to re-use their graphics and imagery.

INTRODUCTION

The operators of public electrical energy supply systems are now being faced with the need to ensure a stable supply voltage in the medium and low voltage grid whilst integrating both renewable energy and the increasing amount of electrical energy fed into the grid from dispersed generation plants. The power flows generated by additional in-feed is likely to significantly increase the need for grid reinforcement, particularly in rural distribution areas where this is often needed to ensure voltage stability.

Conventional distribution transformers fitted with a de-energized tap-changer (DETC) are unable to respond dynamically to changes in voltage under load and will become increasingly unsuitable as the need for greater control in industrial applications and the advent of dispersed generation becomes more commonplace.

The Voltage Regulating Distribution Transformer (VRDT) was designed to compensate for fluctuations in low voltage by responding dynamically to changes, its development borne from the requirement to modify the voltage ratio either automatically or manually when the transformer is on-load and energized as a means of supporting the economic integration of renewable energies into public grids. The range of applications for replacing conventional distribution transformers with VRDTs has subsequently expanded beyond this initial market, offering distribution network operators the capability to run at increased efficiency by reducing the need for grid reinforcement with the possibility of effective network operation utilising a reduced number of grid assets.

Where grids have limited generator power the medium voltage supply may be subject to large voltage fluctuations resulting in the interruption of production cycles, control systems crashing or motor failures. In terms of industrial grid applications the VRDT can ensure the stability of industrial processes via a stable voltage supply within a narrowly defined band.

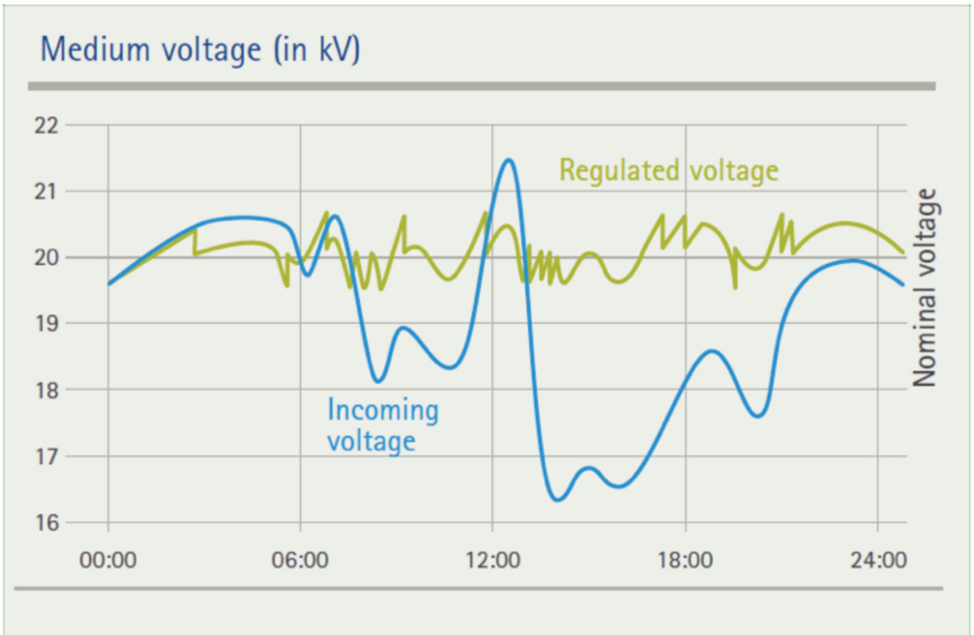
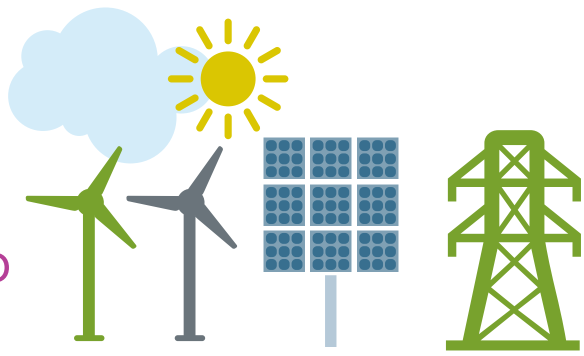


Figure 1: *Medium voltage (in kV)*

THE RANGE OF APPLICATIONS FOR REPLACING CONVENTIONAL DISTRIBUTION TRANSFORMERS WITH VRDTS HAS SUBSEQUENTLY EXPANDED BEYOND THIS INITIAL MARKET.



DETC vs VRDT technology

A conventional distribution transformer uses a DETC on the primary (HV) side to set a voltage ratio ideal for the installation site. By selecting the appropriate transmission ratio, voltage in the LV grid can be maintained within permissible voltage limits. The de-energized tap-changer is set at the commissioning stage and is rarely changed during its operational life.

Various VRDT technologies exist but the fundamental operating principle remains the same, generally consisting of an active transformer part, a control element, and a control unit with regulation. Dependent upon the operating principle, the de-energized tap-changer is replaced or supplemented by a control element which can be operated on-load. The basic function of the control unit enables a desired value of independent LV regulation depending upon power flow.

The transformer and control element encompass the functional unit, with the control element generally fitted either inside or on the transformer tank. The potential change in tank geometry, oil volume, cooling arrangement, etc. may differ significantly from a conventional distribution transformer dependent upon the technical implementation selected.

The option to retrofit this type of regulation control to an existing conventional distribution transformer has not been considered commercially viable to date and is very limited in scope due to the EU regulatory restrictions on the modification of existing pre-regulation transformers.

Dependent upon the technology a VRDT may introduce additional losses from the controlling element and/or extra components, windings, etc. These losses should be taken into consideration when configuring the functional unit to ensure compliance with the EU Eco Design Regulation and this is one area which will be specifically addressed by the impending specification on VRDTs.

Applications

Feeder-based use of voltage regulation distribution transformers with a focus on the medium-voltage grid. Where there is a risk of voltage bands being infringed in a larger interconnected area at the medium-voltage level, e.g. at the end of feeders, due to large fluctuating or constant feed-in and/or consumers in the vicinity of the stations in question.[1]

Use of voltage regulation distribution transformers in all parts of the grid with a focus on the **medium-voltage grid.** Where there is a risk of voltage bands being infringed in a larger interconnected area at the medium voltage as a result of excessive voltages from the high voltage or feed-in connected directly to the primary substation, which cannot be compensated for by the on-load tap-changer on the HV/MV transformer.[2]

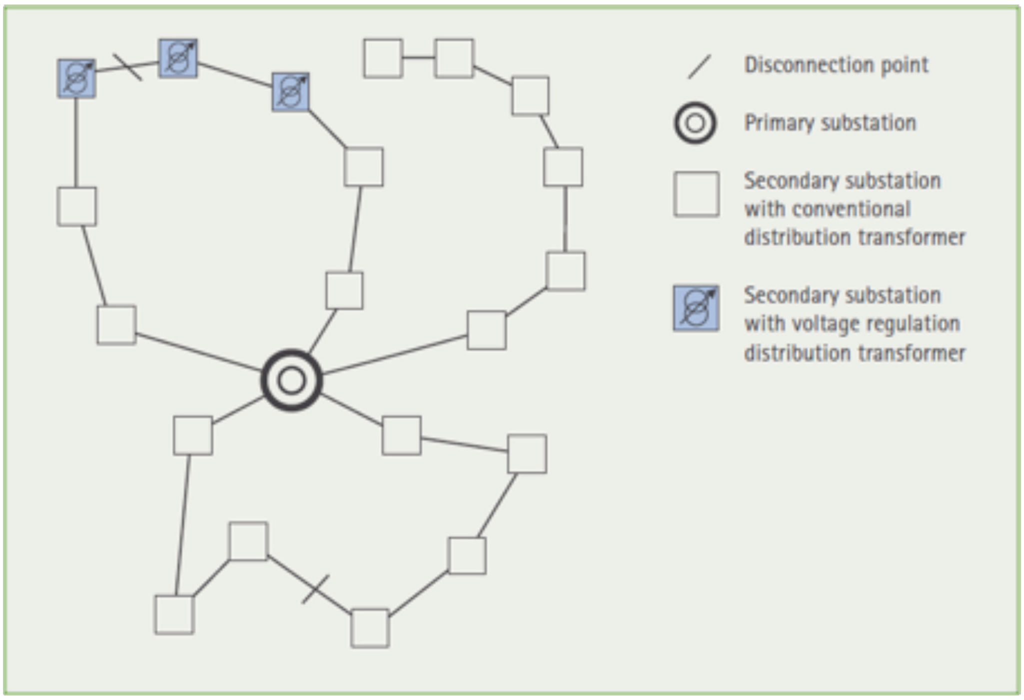


Figure 2: ***Feeder-based use*** *of voltage regulation distribution transformers with a focus on the medium-voltage grid*

[1 & 2] Maschinenfabrik Reinhausen GmbH – The Compact Class for Distribution Transformers (2016).

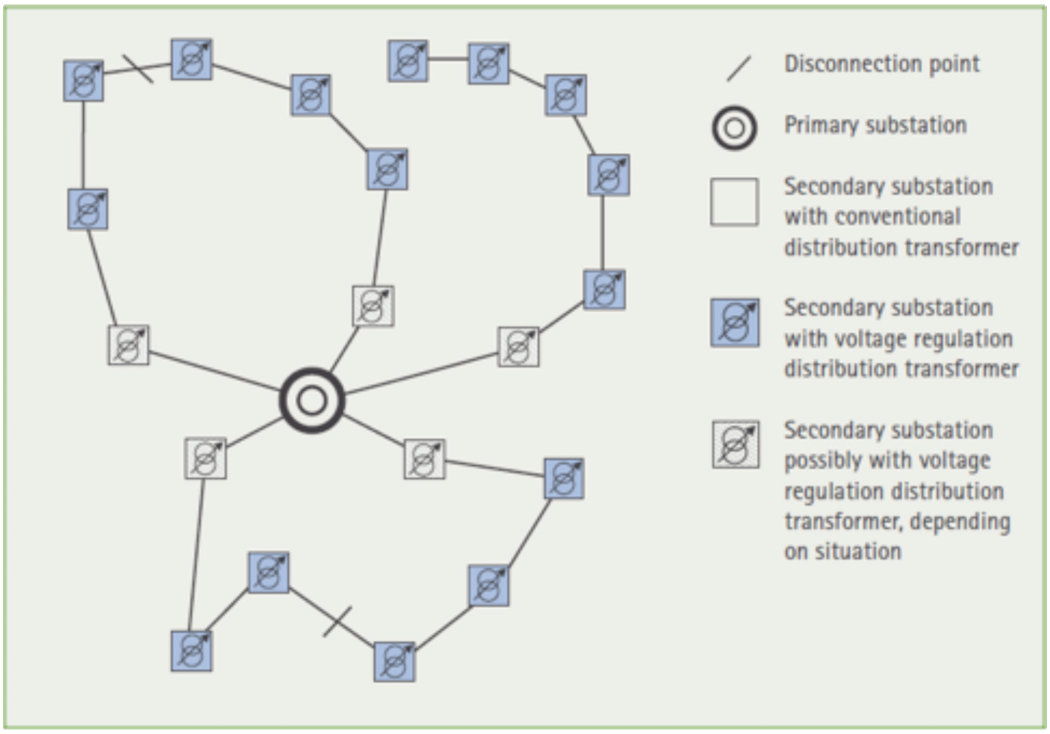


Figure 3: *Use of voltage regulation distribution transformers **in all parts of the grid** with a focus on the medium-voltage grid*

References to existing and 'in work' standards

Standard	
EN 50160	Voltage characteristics of electricity supplied by public distribution networks
EN 50588-1	Medium power transformers 50 Hz, with highest voltage for equipment not exceeding 36 kV
EN 61000-3-11	Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems
EN 61850	Communication networks and systems for power utility automation
EN 60870-5	Telecontrol equipment and systems (Parts 101 – 104)
IEC 60068-2	Environmental Testing
IEC 60076	(all parts) Power transformers
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 61000-6	Electromagnetic Compatibility
IEC 61010	Safety requirements for electrical equipment for measurement, control and laboratory use

Initial work carried out on a proposed EN specification by CENELEC has subsequently been adopted up by IEC as part of the Dresden Agreement and will be issued as part 24 of the IEC 60076 series.

Commercial Aspects

When using a VRDT, the grid operator will take into account investments and operating costs. From a regulatory standpoint, using a VRDT constitutes an investment in the grid but the question of whether a VRDT is an economical cost-effective alternative to conventional grid reinforcement depends on how much of the latter can be substituted.

An efficient distribution grid has as little equipment as possible, enabling savings in both investment and operating expenses. The number of secondary substations needed for a grid area is determined firstly by the maximum demand to be covered and/or the maximum feed-in to be transported and secondly by the maximum possible distance between the secondary substation and grid connection points from a voltage standpoint. Using VRDTs could reduce the total number of secondary substations as they dynamically adapt the voltage and permit a larger electrical supply radius around each secondary substation.

Benefits

A significant benefit of the VRDT comes from the advantage of greater flexibility in implementation and a degree of robustness against future uncertainties. Protracted planning and approval procedures to the addition of power generation may be necessary for cable reinforcement whereas the relative period associated with the planning, procurement and implementation of a VRDT facilitates a much quicker response.

In comparison to other solutions for voltage control in the distribution grid e.g. reactive power inverters or distributed energy storage the VRDT appears more attractive when taking into consideration the lineage and provenance of the technology upon which it is based, The use of a VRDT allows a high degree of compatibility with existing network infrastructures, as there is essentially no difference between the operation of a conventional distribution transformer and a VRDT other than dynamic voltage regulation.

Stabilizing Industrial Processes in Volatile Grids

For industrial processes to run steadily and reliably, they require a stable voltage supply within a narrowly defined band. In grids with limited generator power, long distances or volatile consumers and producers, the supplying medium voltage may be subjected to large fluctuations in voltage. As a result, production cycles may be interrupted, motors may not start or control systems may crash. This can cause serious damage, especially in sensitive industrial processes. Hospitals are particularly critical in this respect. In addition to direct impacts on processes, frequent changes in voltage may also have a negative impact on the life of equipment.[3]

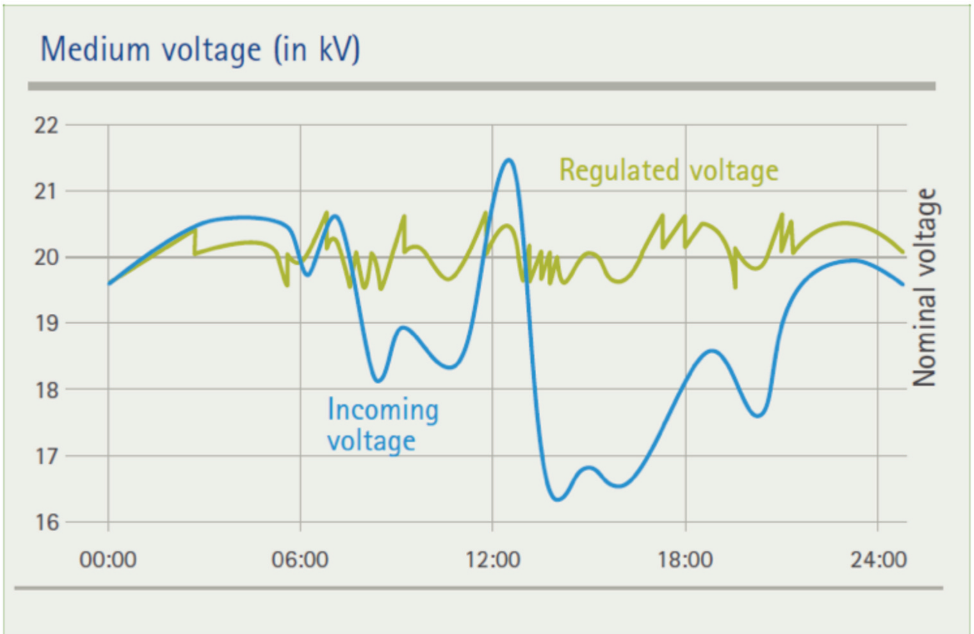


Figure 4: *Medium voltage (in kV)*

Reducing Energy Costs by Optimizing Voltage

Energy consumption for loads such as conventional, i.e. non-frequency-controlled motors, heaters or lighting is affected by factors such as the voltage with which the equipment is supplied.

If such equipment is supplied with a higher voltage than needed, e.g. because the medium voltage is higher than nominal voltage, the equipment consumes more energy than needed.

Using a voltage regulation transformer in the industrial distribution grid allows equipment to be supplied with a voltage actively optimized for it. This reduces energy consumption without limiting the equipment's function.

The voltage regulation transformer's controller balances the voltage between what is available and what is ideal for consumption.

Before the voltage falls to a level where equipment operation is at risk, the voltage regulation transformer intervenes and restores the voltage to a level which is ideal for equipment energy consumption.[4]

Voltage regulation transformers improve reactive power capability by decoupling the secondary voltage from the grid voltage at the generator, voltage regulation transformers can ensure that the generation plant is always supplied with its nominal voltage and use can thereby be made of full reactive power capability.[5]

[3, 4 & 5] Maschinenfabrik Reinhausen GmbH – The Compact Class for Distribution Transformers (2016).

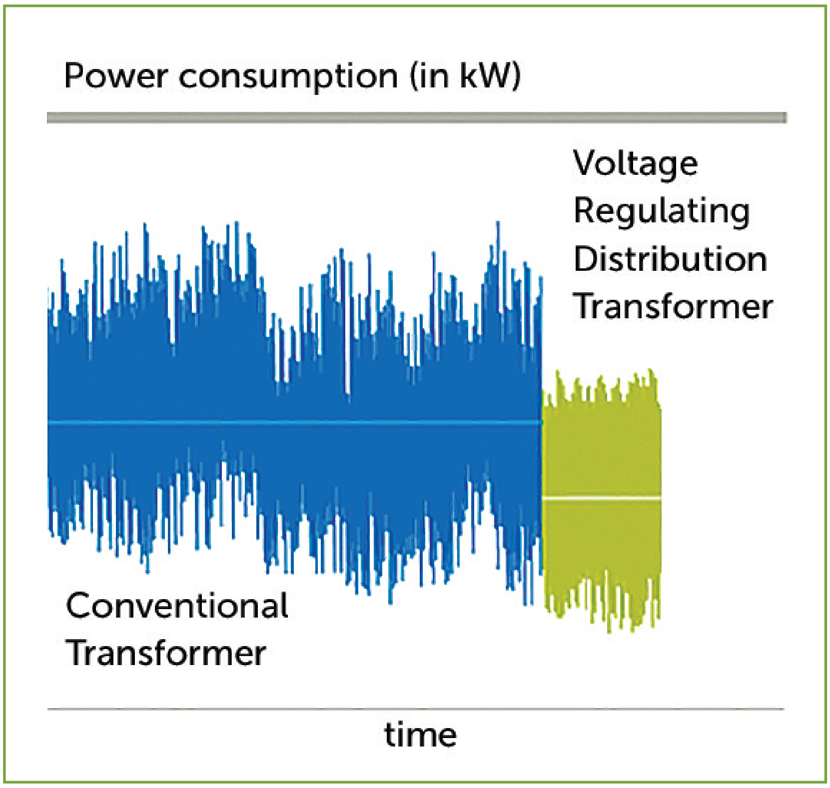


Figure 5: *Power consumption (in kW)*

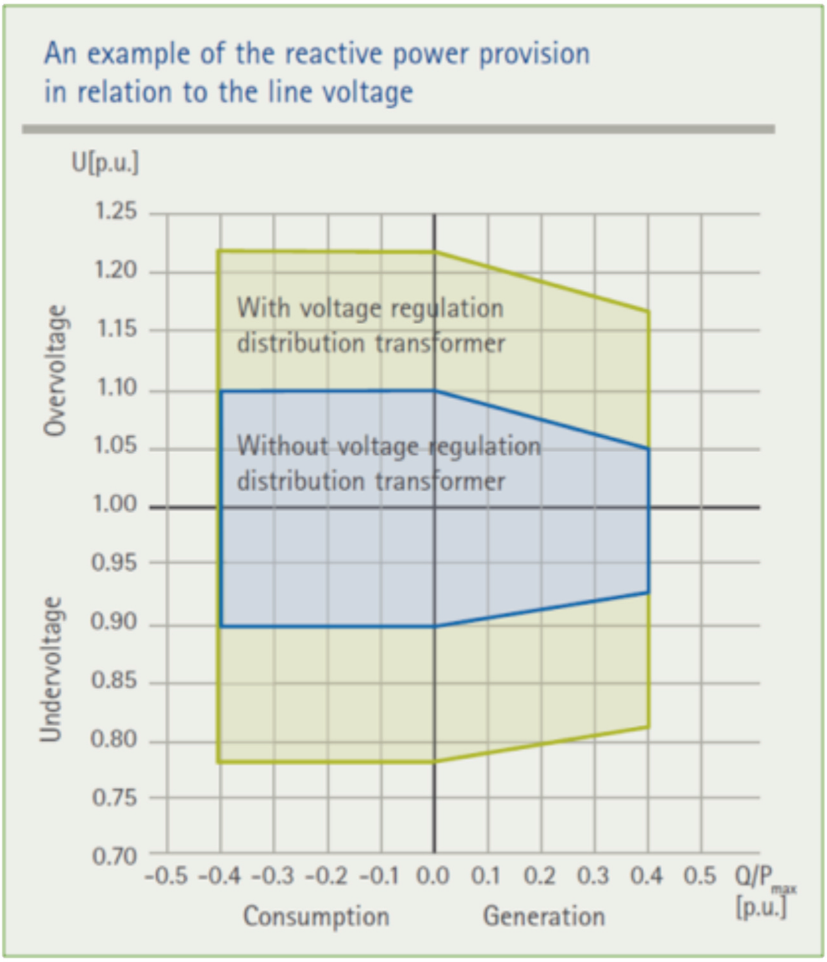
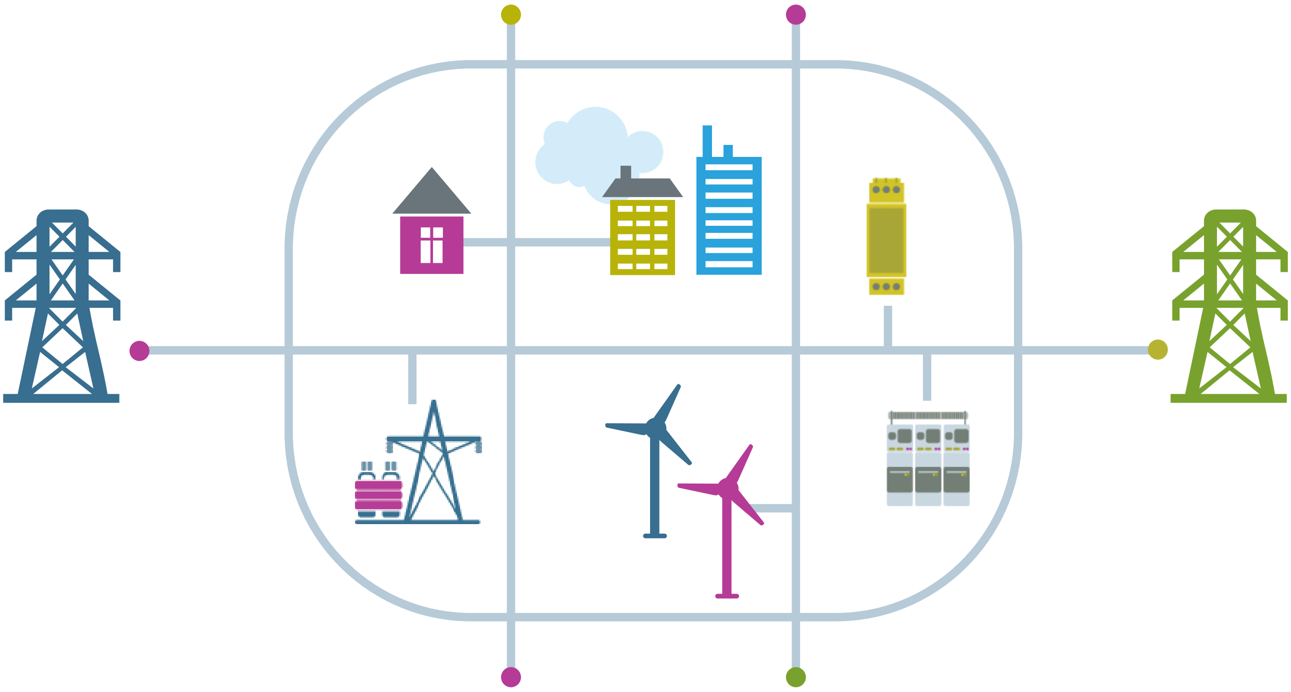


Figure 6: *An example of the reactive power provision in relation to the line voltage*

Summary

- The VRDT is a distribution transformer with an additional control element and control unit whose main characteristic is the ability to change the voltage conditions on-load.
- The product is readily available, having been through the process of industrialisation by many reputable equipment manufacturers over a period of 5-6 years.
- The primary applications are rectification of voltage band problems, optimization of grid topology and optimization of reactive power management.
- Integration into existing substations/compact substations is feasible dependent upon the technology adopted e.g. any technical solution which does not significantly modify the existing equipment footprint.
- Distributed Generation systems are increasingly being developed and installed in the electricity network, most of which, particularly small-scale renewables such as wind turbines, photo voltaic and micro-CHP systems are connected to the domestic LV network. This type of installation is likely to increase rapidly over the next decade and Network Operators must ensure that a safe, reliable and stable supply of electricity is available throughout the transition to a reduced carbon future. One UK DNO[6] has already begun trialling the VRDT concept by installing a number of VRDTs on the system with a view to analysing the practical benefits of the application.



6 M. Anzola, D. Walker, D.Neilson & M.Wright – Voltage Regulating Distribution Transformers for LV Network Control and System Efficiency (CIRED, Glasgow June 2017)

Rotherwick House
3 Thomas More Street
London E1W 1YZ

www.beama.org.uk