EVOLUTION OF THE TELECOM POWERING STRATEGY: MOVING TO A COST EFFECTIVE AND RELIABLE SOLUTION USING REMOTE POWERING

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ABSTRACT

Many Telecom operators and engineers do not take into account the whole powering network aspects when a new service and/or a new technology is going to be launched to the market.

Here, we present a new concept for the engineering and the implementation of powering networks for the telecom systems - the so called remote powering. Since the local power feeding of equipment can be eliminated based on this concept, we consider remote powering as a very efficient solution.

INTRODUCTION

Presently, about 95% of the telecom installations are equipped with local powering. This simple and common solution causes a great deal of problems. For instance, a high cost for maintenance is incurred related to the wide operating temperature range of the batteries and their large number.

Currently, each solution had to be studied, then prototypes had to be designed and tested before the final product is introduced. These activities require additional training for the engineers as well as the maintenance crew. Apparently, this generates extra costs for the telecom network operator.

The system solution presented here is tested on both laboratory and field trials that will introduce a new concept for powering the future telecom network infrastructure. This concept enables operators to enhance flexibility and substantially reduce the time to market. Moreover, no new studies for the right powering scheme have to be pursued upon the arrival of new services.

THE CENTRAL EXCHANGE IS THE DRIVING SOURCE

Centrally located power systems are well known in term of high reliability, low maintenance and services. Mostly provided with digital controllers and a large number of functions for maintaining and testing the batteries. Control and supervision via Internet are now commonly available.

However, the central office power supply is never used to its maximum capacity. The new exchanges utilise even less DC power and the co-location opportunities are increasing. Consequently, for any existing exchange there are two new resources that are available namely: excess power and availability of physical space. These two reserves are the main reasons for the proposal of remote powering solution.

THE EVOLUTION OF POWERING NETWORK FOR THE EXCHANGE

Over the years the evolution of the equipment technology, led to a gradual reduction of DC power. Now we believe that the minimum requirements is reached. In the future, due to new data services, the power demand will increase in the next decade. However most of this new equipment will be AC-powered. One of the need is to add high power DC/ AC inverters for this application to the existing DC power plant. Currently the exchanges accommodates also computing equipment that are AC powered e.g. IP routers and switches. A commitment for the computing industry is now necessary in adopting similar powering schemes as used in exchanges. (ETSI is considering a higher voltage in a new proposal).

In the near future, a part of the active equipment will be moved outside the exchange and need also to be powered. This concerns in particular equipment such as DSLAM's, MUX, APON, ONU etc. which are placed in an outdoor cabinet.

POWERING THE REMOTE EQUIPMENT: A SOURCE OF PROBLEMS

With the introduction of VDSL technology, it is no more possible to run 5 - 6 km of copper cables. The cable length will be reduced to a max. of 1.5 km. This depends on the cable quality and the required bandwidth. So one part of the exchange (DSLAM) needs to be moved outside of the central exchange to a street cabinet and to be powered.

The choice of the powering scheme and topology can have a big impact on the time to market. Using local powering system, it is possible to build a simple network, with that a large number of small units need maintenance (e. g. replacing or testing batteries). This will cause high operation costs.

Moreover the connection to a local powering system (local energy supplier) implies the constraints listed below:

- Contracts to be made with the energy provider for each location
- Engineering of the local power feeding
- Metering
- Lightning protection to be installed
- Power cable need to be installed (excavation, installing pipe etc…)

In Switzerland a lengthy approval procedure through the federal institute has to be pursued.

USING CLUSTER REMOTE POWERING FOR SMALL UNITS

After many studies, an optimal topology of remote powering is reached that combines geographically the remote equipment grouping 5 to 10 units in each cluster .

The topology is flexible enough, and it can be adapted to each case without modifying the concept.
The cluster topology described in Fig. 1 shows also the selected solution for measurements in the laboratory. In practice, the clusters (C1 and C2 in Fig. 1) may be physically located in one of the cabinets or in any other suitable location (manhole, underground cabinet etc.).

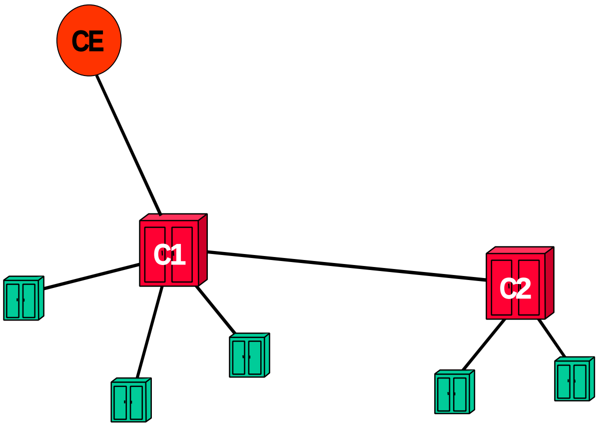

Fig. 1 Cluster remote powering concept

The space needed for one cluster box (see Fig. 2) is about 200 mm x 150mm x 350mm including transformer and fuses.

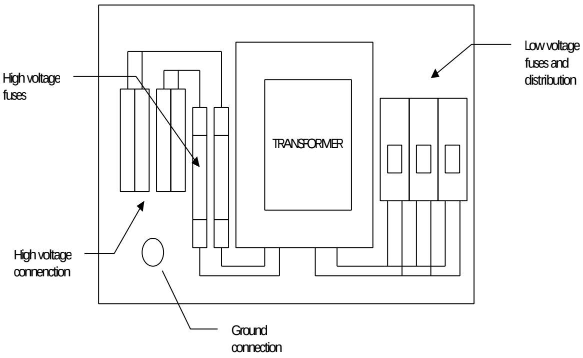

Fig. 2 Clusterbox arrangement

The distance between CE and C2 should not exceed 5 to 6 km. In order to minimise the energy transport losses, it is necessary to increase the voltage. The voltage level depends essentially on the distance, on the costs of the components and on the type of cable. Old copper cables can be used for this purpose, but they will limit the voltage to about 400V. This is due to the poor electrical isolation of the cable.

THE RING TOPOLOGY

The problems with the ring topology are well known. This is in the choice of the over-current protection (fuses). This depend on the size of the ring and the power ratio between the power source and each user. The geographical position of the equipment on the ring could be critical. The topology is not flexible and difficult to upgrade. Fuses and their related issues are still problematic on this topology.

REMOTE POWERING - Advantages

Remote powering has several advantages namely on the cost and reliability side. Due to the smaller number of power feeding stations the mobile generator strategy can be applied. In case of long outages only one mobile generator is necessary to restore the operation of the whole network. Therefore, Supercaps® can be used and the most critical point of failure in the powering chain, the battery, can be eliminated. The need of sophisticated power Controller in the remote unit is no more necessary. This results in a simplified maintenance, a decreased dependence on energy providers and in a higher reliability of the network.

REMOTE POWERING - Laboratory trials

The adopted solution, reflected in the cluster topology described in Fig. 1**,** was tested in the laboratory using standard hardware. The adopted voltage was 1000 V. The energy is transported in a separate cable. The max. load of each end-user (in this case broadband cabinet) is assumed to be about 120W [2].

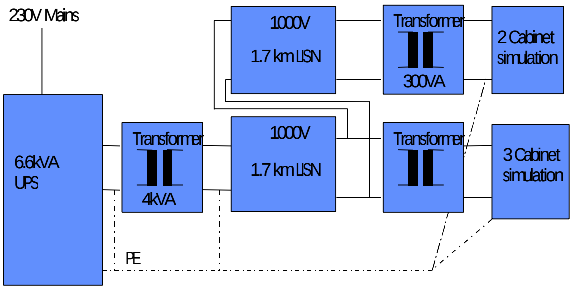

Fig. 3 Laboratory trial set-up

Hardware Configuration

Transformers The primary transformer was defined as follows: 4kVA / 50Hz / 230V / 1000V . The secondary or cluster transformers were defined as follows: 300VA and 500VA / 50Hz / 1000V / 230V . The secondary transformers are designed with the following criteria:
2 x 120W / PF 0.75 = about 300VA
3 x 120W / PF 0.75 = about 500VA.
The chosen topology can deliver power for 5 broadband cabinets. However, the primary transformer, which is located at the CE, can provide power for about 20 120W-units including the losses.

Loads The following loads were used for the laboratory trials:

- Resistive load for the maximum power rating
- Non-linear load according to EN50091-1 to simulate the real case and load the cables with a maximum current.

In the first phase of the trials the cables were not available. They were simulated with a Line Impedance Simulation Network (LISN), which is basically a combination of resistors and capacitors able to simulate long lines. The LISN capability correspond to about 3.4 km of cable.
In the second phase, two types of cables were tested:

- 3 x 4mm2 LNPE PURWIL non flammable 1 kV cable unscreened (1km)
- 2 x 4mm2 LN Betaflam FE5 1kV screened with 2 copper bands (1km)
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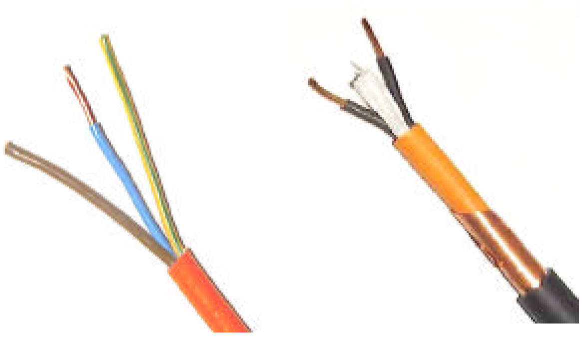

Fig. 4 Cables used for the test

Tests carried out

The goal of these tests was to get rapidly significant and relevant results to be considered by the engineering people when they build a remote power feeding network using cluster topology. The following tests were performed in the Swisscom laboratory:

- Efficiency and voltage measurements
- Inrush current measurements
- Short dips and interruptions
- Short circuit rejection
- Surge protection / filtering
- Cable characteristics

Results

Efficiency and voltage measurements They were made with the two types of load and the 2 x 1.7km LISN using a precision power analyser. The results are summarised in the table below:

Load	Non-linear	Linear (resistive)
Input	Pin = 799W; Uin = 229.53V; Iin = 4.608A; PFin = 0.755 ind	Pin = 1024 W; Uin = 229.2 V; Iin = 4.85 A; PFin = 0.918 ind.
Output	Pout$_{500}$ = 354W; Uout = 235V; Iout = 2.12A; PFout = 0.71 Pout$_{300}$ = 218W; Uout = 234V; Iout = 1.26A; PFout = 0.74	Pout$_{500}$ = 509 W; Uout = 231.4 V; Iout = 2.20 A; PFout = 1.0 Pout$_{300}$ = 304. W; Uout = 230 V; Iout = 1.32 A; PFout = 1.0
LISN	7x110nF + 6x5?	7x110nF + 6x5?
Efficiency	0.716	0.797

Inrush current measurements The main goal of the inrush current measurement key to prove that the primary transformer can be connected to a weak mains source, such as a UPS or inverter. These sources provide only a limited inrush current capability. The secondary goal is to show the quality of the HV link when a load (equipment) is connected. The worst case of inrush current is achieved with a non-linear load (charging of the input capacitors with a high-current peak).

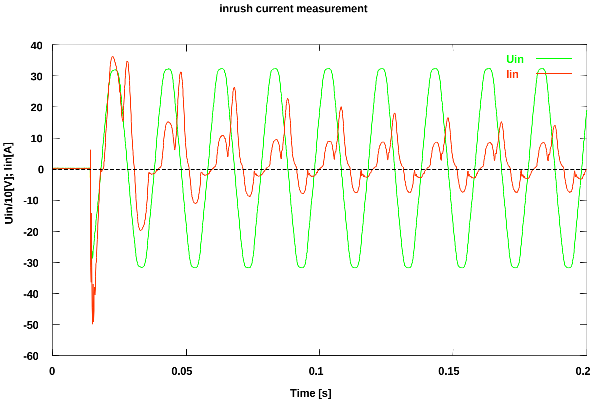

Fig. 5 Inrush current of the primary transformer connected to a UPS

From the measurements, some general conclusions can be drawn. The inrush current capability of the source is a very important criterion for the engineering of the transformers. The inrush current of the primary transformer should meet the ETS 300 132-1[5] standard. Due to this limitation, it is not recommended to use expensive toroidal transformers.

Short dips and interruptions The tests were performed with resistive and non-linear load, the HV-link was measured with a HV-probe. The results are summarised in the table below:

	Test 1	Test 2	Test 3	Test 4
ΔU	>95%	30%	40%	>95%
Duration	10 ms	500 ms	200 ms	5 s
Requirement	No over voltages No over currents No oscillations No fuse blowing			
Result	OK	OK	OK	OK

This system is not a power supply but the relevant tests are described in the EN 300-386 [3] standard. The performance criteria described in [3] are not applicable.

Short circuit rejection This trial was done to demonstrate the excellent behaviour of the system regarding short-circuit rejection in a fault situation. The fault was produced on the secondary side of the 300VA transformer with a switch. The fuse was intentionally chosen with twice the current rating of the transformer to produce a worst case condition.

After many trials, the measurements showed that a maximum of 60ms blowing time can be expected without significant voltage drop on the HV-link. At the far end of the system the voltage drop is about 10V.

Surge protection Two trials were performed on the system with the following goals:

1. to observe and measure the filtering performance of the whole system when a surge pulse, according to EN61000-4-5 [6], is applied to the input of the primary transformer .
2. to obtain figures from lightning pulse directly applied to the duct or pipe, with metal pipes as a worst case.

For the first trial the set-up was the same as the one shown in Fig. 3 and the voltage was always observed after the 500VA and the 300VA transformers.

The used coupling voltage was 2 kV L-PE. After the 500VA transformer a surge of about 120V remains, whereas after the 300VA transformer, the surge is reduced to about 20V.

For the tests between L-L (1kV) the surges disappear after the first transformer.

The set-up for the second trial was realised with the aid of a big pulse generator with 100kA (8/20µs) surge capability.

The tests were performed with two types of cables. The peak current was increased from about 10kA to 40kA in 10kA steps, which represents a realistic lightning impact on the cable. The transients on the input and output voltages were recorded.

The ground wire or the screen was connected to the ground at both ends.

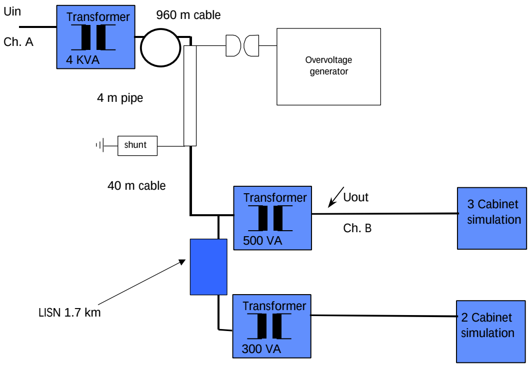

Fig. 6 Lightning protection test set-up

The surge protection measurements demonstrate the filtering behaviour of the transformers. In the second test, the injected voltage along the pipe reached peak values of up to 15 kV. The attenuation of the injected signal is very important, and the experiment showed, that, after 40m (of cable), the signal is smaller than 100V and practically disappears. In conclusion no extra lightning protection is needed.

REMOTE POWERING – System Complexity

The complexity of medium voltage AC remote powering from the CE compared to the local powering is considered for new installations.

Considering the whole powering scheme, remote powering reduces the amount of components and features needed at the remote location.

Fig. 7 Space saving potential

Eliminating batteries at these locations will considerably reduce the complexity of the power system inside the cabinet. Remote feeding using the telecommunications' companies own power eliminates the need for metering and special connecting boxes. This result in saving place in the cabinet.

REMOTE POWERING – System Costs

For cost comparison, the installation cost of the local powering is taken into account as well as the fact that the powering cable and the fibre cable are installed at the same time. The topology considered is based on 20 remote locations, each with a power-consumption demand of 120W. For the comparison the following assumptions were made:

Local powering

- 4 h batteries back-up (e.g. 48V / 15Ah)

- Metering units and connection boxes
- Power systems controller with battery features
- Installation of about 50m of power cable
- Maintenance (2h / year)

Remote cluster powering

- 7 transformers 300VA
- 10 km of cable
- 1 transformer 4 kVA
- Cost savings in the cabinet HW
- Simple power system controller
- Maintenance (10h / year)
- CE equipment
- Installation costs

With the above assumptions and considerations, the cost savings opting for remote cluster powering are about 30%, compared to local powering. Even if each remote location has its own transformer, the cost savings still add up to 25%. The costs of operation and engineering are assumed to be equal.

The table below give a cost comparison basis between local powering and remote powering

Yearly costs	local powering	remote powering from DC	remote powering from AC UPS
Investment (12% / 10 years)	31762	15241	13660
Maintenance	6000	400	160
Energy	5040	18900	10000
Total costs / year	42802 1)	34541 2)	23820 3)

Remarks:

1) The backup time for local powering is 4h and in special cases 8h.

2) The backup time for remote powering is 4h. After this time a mobile or stationary generator will run. This means an infinite backup time.

3) The backup time is about 30 min. After this time, it cannot be guaranteed that a generator will run.

ENVIRONMENTAL CONSIDERATIONS

Due to the large deployment of small remote units in any kind of telecommunication domain (switching, transmission etc.) some environmental consideration should be made.

The first one is to consider the backup strategy: when a mains failure longer than the backup time occurs is not possible to serve each point with a mobile generator. The advantage of remote powering is that only one generator is needed at the CE.

The second consideration is based on the short lifetime of small battery units. These are actually the cause of the most problems in applications outside of the CE. Beside the dispersion of a lot of small units the concentration of larger batteries in a single location can be an advantage.

The third consideration in the environmental impact. Smaller units can be installed taking advantage of place saved inside the cabinet. Larger units are even difficult to be approved and installed.

The fourth consideration is the pollution due to the maintenance people going with a car for maintenance at the remote unit.

ENGINEERING TABLES AND CALCULATIONS

In order to build the powering network a few calculations needs to be made. Considering a tree topology is possible with a simple formula to draw engineering tables.

The required cable cross section of a given topology can be calculated for a single phase system using the following formula:

$$\Delta U = \frac{P.l.100.\left(Rw.\cos j + Xl.\sin j\right)}{U^2.\cos j}$$

where:
P: transmitted power [kW]
l: distance [m]
Rw: specific cable resistance [Ω/km]
Xl: specific cable inductance [Ω/km]
U: nominal voltage [V]
ΔU: Voltage drop [%]

φ: phase angle of the load

The plot below were calculated for a single copper wire at a temperature of 20°C using the formula above. This means that the length should be multiplied by a factor of 2.

The load is assumed to be linear at cos φ=0.9 and the frequency is 50 Hz.

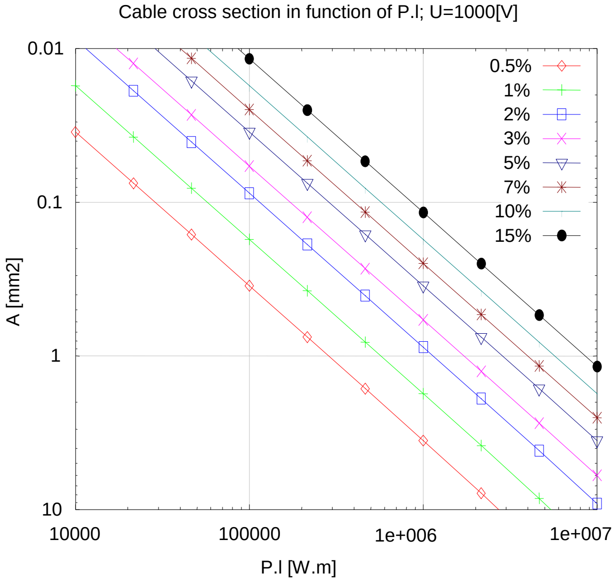

Fig. 8 Example of calculation table for 1000V

GROUNDING

The grounding concept of the “HV link” for the AC remote powering is described in the figure below.

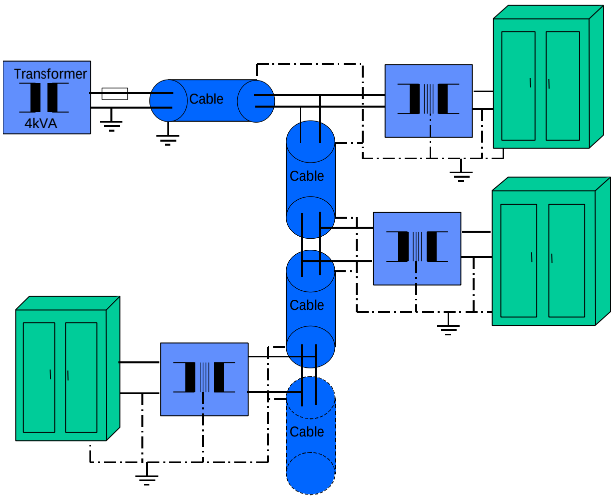

Fig. 9 Grounding concept

The grounding of the system is made in the well known, standard manner. The secondary of the main transformer as well as the transformer core are grounded at the CE. If a screened cable is used, the screen is always connected to the ground on both sides. The “HV link” is only connected to the ground at the CE. One option is to connect the HV link to the ground at each distribution point with a spark gap. The secondary of each transformer as well as the transformer core are grounded in the cabinet.

REMOTE POWERING - Applications

At this time the first step on the project is done. The deployment of VDSL technology will follow soon. Swisscom will prefer AC remote powering against DC powering through copper pairs. The major problem is now the approval procedure from the authority. A detailed business case should be done for a given number of units and the special topography of the Switzerland. The considered applications are: primary VDSL, Transmission equipment (copper, fibre) and some other small remote equipment.

CONCLUSIONS

The availability of an uninterruptible energy supply for outside plants is a challenge for network operator. The proposed remote powering scheme improves the availability of the services and reduces the maintenance costs compared to local powering.

Considering the technical point of view, the results show that, the use of screened cables are more suitable for this solution because of their higher EMC immunity. This has been proven during the outdoor surge protection tests as it demonstrated a very good attenuation against the applied surge pulse. During this test, the surge pulse had practically disappeared after 40m of cable length. It should be mentioned here that the magnetic coupling and the ratio between primary and secondary of the transformer affect the surge attenuation too.

The examples demonstrate the simplicity of the topology. These will help engineers to calculate a value for each component used in the AC remote powering chain.

The proposed grounding scheme is similar to that normally used for outdoor cable systems. Due to the low energy level of the systems (some kW) the ground connection of the screen on both sides could be realised without influencing the dimensioning of the cable.

A cost comparison between two AC remote powering concepts was carried out and it further demonstrates advantages of the AC remote powering made from the DC power facilities of the central exchange.

The results show that remote AC powering is both technically feasible and reliable solution. It should, therefore, be considered as a viable alternative to the existing solutions. A quantitative analysis of the cost benefits to a telecom operator were investigated and the results were also presented.

A full report is available at www.eurescom.de: Deliverable 7 of the Project P917GI “BOBAN”.

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