# A Review of the Power Distribution System in the Telecommunications Sector

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## ABSTRACT

 *The telecommunications sector consumes a significant amount of power from the electric utility grid for its functioning. In a typical telecommunications center, about half the energy consumed is delivered to the load, with the rest is lost in power conversion, distribution and cooling processes. Higher voltage DC is, thus being proposed as an energy efficient distribution option.*

*This paper takes a look at the -48 V power distribution widely used for providing power to telecommunication equipment, and at the methodology used for grounding and bonding of both the power system and the powered telecommunication system. An analysis of the benefits of the +380V DC power distribution system compared to the current -48V DC power supply system in telecommunications sector is also presented.*

*High-frequency AC (HFAC) power distribution systems have also been the subject of great interest. This paper also presents a review of the different HFAC power distribution architectures and is focused on the HFAC power architectures and topologies for the telecommunications system. This paper also presents the concept of green telecommunication networks and provides information about the power consumption within fixed line and wireless communication networks. It outlines the significance of energy efficiency in modern and future telecommunication networks and suggests directions for optimizing network performance in terms of energy demands.*

*Keywords: Global System for Mobile Communication (GSM) Network, Base Transceiver Systems (BTS), High-Frequency AC (HFAC) Distribution, High Voltage DC (HVDC) Systems, Radio Frequency (RF).*
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## 1. BASIC TELECOMMUNICATIONS ARCHITECTURE

 Telecommunication systems, especially, mobile handsets have changed the life of people dramatically, especially, since the turn of the 21st century. Mobile phones have a variety of protocols, with the help of which, they can be connected to one another, throughout the globe.

One of the most popular networks for mobile phone communication is the Global System for Mobile Communication (GSM) [1].

In a typical GSM network, a mobile phone connects with the nearest Base Transceiver System (BTS). A Base Station Controller (BSC), in turn, controls several BTSs. Several BSCs are controlled by the Mobile Switching Centre (MSC). The MSC maintains a connection with several other MSCs, a Public Switched Telecom Network (PSTN) and an Integrated Services Digital Network (ISDN).

A typical GSM network is composed a number of BTSs [1]. When a call is placed through a mobile phone from the user's end, it first connects the nearest BTS tower. The area that a BTS covers is called a cell area. When a mobile phone is in motion in the active mode, it crosses the boundaries of a particular cell area, and in turn, switches from one BTS to another.

We find that a large number of communication towers are thus, being installed, to cater to the huge subscriber base of mobile telephony.
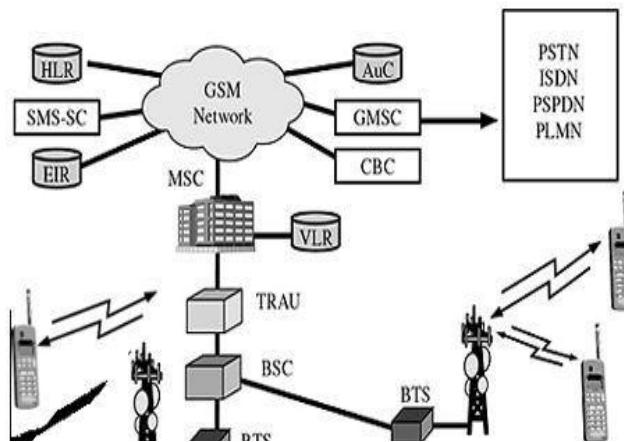
Fig. 1: Basic Architecture of a GSM Network

## I. POWER DISTRIBUTION SCENARIO FOR THE TELECOMMUNICATIONS SECTOR

The most common supply of electrical power worldwide, from the electrical power utility is in the form of AC at a frequency of 50 or 60 Hz. Nowadays, we find that the majority of the loads, residential or commercial, have, however, become digital in nature and thus, require conversion of power from AC to DC. We also find that, both energy storage and the rapidly expanding renewable energy generation systems require DC output. The telecommunications industry has been using -48V DC power systems with backup batteries for a long time. Many telecommunication sites, particularly in urban areas, were constructed more than 30 years ago and do not conform to today's requirements for ICT systems. The historical reason for using the nominal voltage of -48V DC was safety. The analog exchange systems that were used, consisted of low-voltage copper lines used at home and the electro-mechanical relays that were being used, required frequent manual intervention in the telecommunications centers [2].

The 1-wire distribution system of power from the source to the load is possible within narrow ranges of voltage, power, and distance only. It uses the earth as a power-return conductor and requires low resistance connections of metallic conductors for earthing.

The 2-wire distribution system is much more common than the 1-wire distribution system and is used for powering both the AC and DC systems. This distribution system uses copper wires as both 'power' and 'power-return' conductors. The power-return conductor is grounded and has a protective function in addition to its function of carrying the current.

The 3-wire distribution system employs a power conductor, a power-return conductor along with a protective-grounding conductor. The power-return conductor and the protective-grounding conductor are usually grounded closer to the power source. From the grounding point, the power-return conductor is treated like a power conductor.

There are three conductors that are connected to each communication equipment entity: a -48V conductor, a BR conductor, and an equipment-bonding conductor. The first two conductors enter the equipment, while the third conductor terminates at the metallic enclosure, as illustrated in Fig. 2.
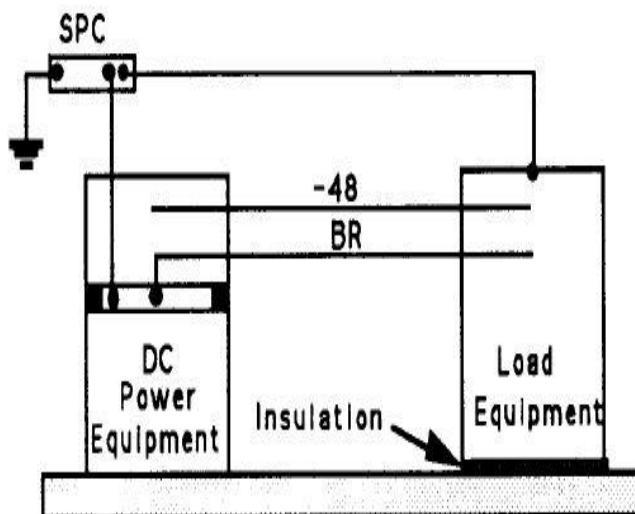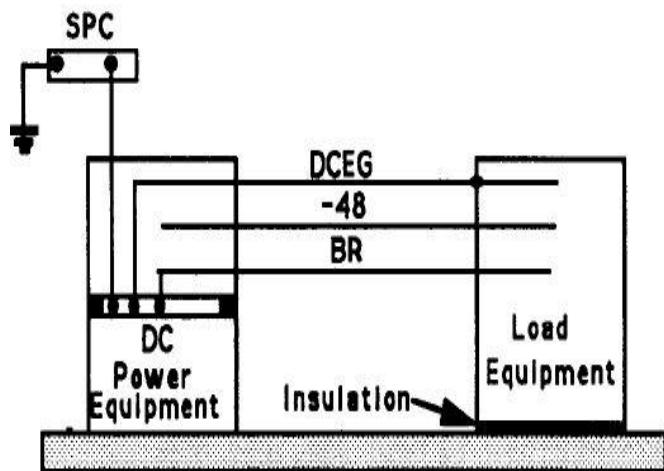


**Fig. 2: A schematic showing the DC powering at a telecommunications site**

A look at Figs. 2 and 3 indicates that the DC powering and grounding scheme is clearly very similar to a 3-wire AC distribution system.

**Fig. 3: Schematic of a 3-wire DC distribution system**

The analogy between the conductors is illustrated by the following table

**Table 1: Analogy between conductors in AC & DC Systems**

| Conductor | AC Powering | DC Powering |
|---|---|---|
| Power | Line | -48V |
| Power Return | Neutral | BR |
| Equipment Grounding | ACEG | DCEG |

The use of data communication equipments, such as servers or computers, is gradually increasing at a telecommunications site due to the huge subscriber base. The load density of data in a communication equipment at present is about 100 times more compared to the traditional telecommunication switching systems that were used during the 1960's and 1970's. This is expected to increase even further in recent years.

This rapid increase in load also significantly impacts the power distribution methods. For a newly constructed facility operating at -48V DC, cabling issues, may not be as important as the space and wiring layout in the planning stages, but they are equally significant in nature.

Powering of the telecommunication systems is becoming an increasingly important aspect due to the following factors:
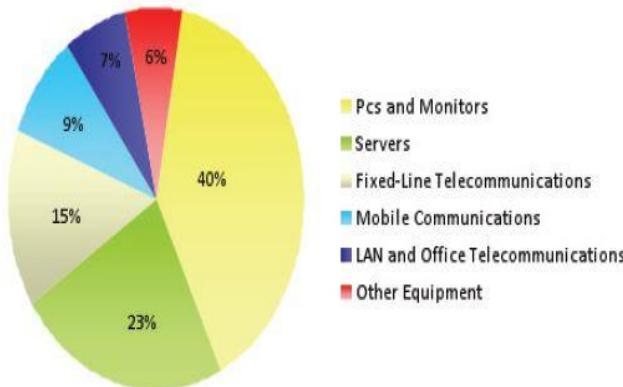
- Cost of the power part of the system has become relatively high, especially with remote-handling equipments.
- The cost of energy is also a considerable factor.
- The electrical energy fed to the system is transformed to thermal energy, which has to be removed later.
- Power supply and distribution systems also have a growing influence on the reliability of the system.

Data and telecommunications centers are major energy consumers, with an energy consumption of about 150 TWh worldwide, as of 2017. A very large data center requires of the order of 10 MW of power to support the computing infrastructure and this is expected to increase to 50MW in the future. In a typical data center, about half of this power is delivered to loads, such as, microprocessors, memory and disk drives. The rest of the power is lost in conversion of power, distribution of power, and cooling of the sophisticated equipments, which, in turn, results in the generation of higher utility bills. It has also been shown that the capital cost of the power delivery and cooling infrastructure required for a data centre already exceeds the purchase price of the servers that it is supposed to support, and it is expected that the life-time energy costs of a server will also exceed its purchase price in the near future.

Traditionally, power distribution is at 400/480V AC for the data centers and at -48V DC in the telecommunication facilities [3], [4]. The use of higher DC voltage as an energy efficient distribution option for both data centers and telecommunication facilities, compared to low voltage DC distribution, has been in discussion for more than a decade. The potential of high voltage DC to improve the utilization of distributed renewable energy generation and its lower component cost has also been pointed out through various tests

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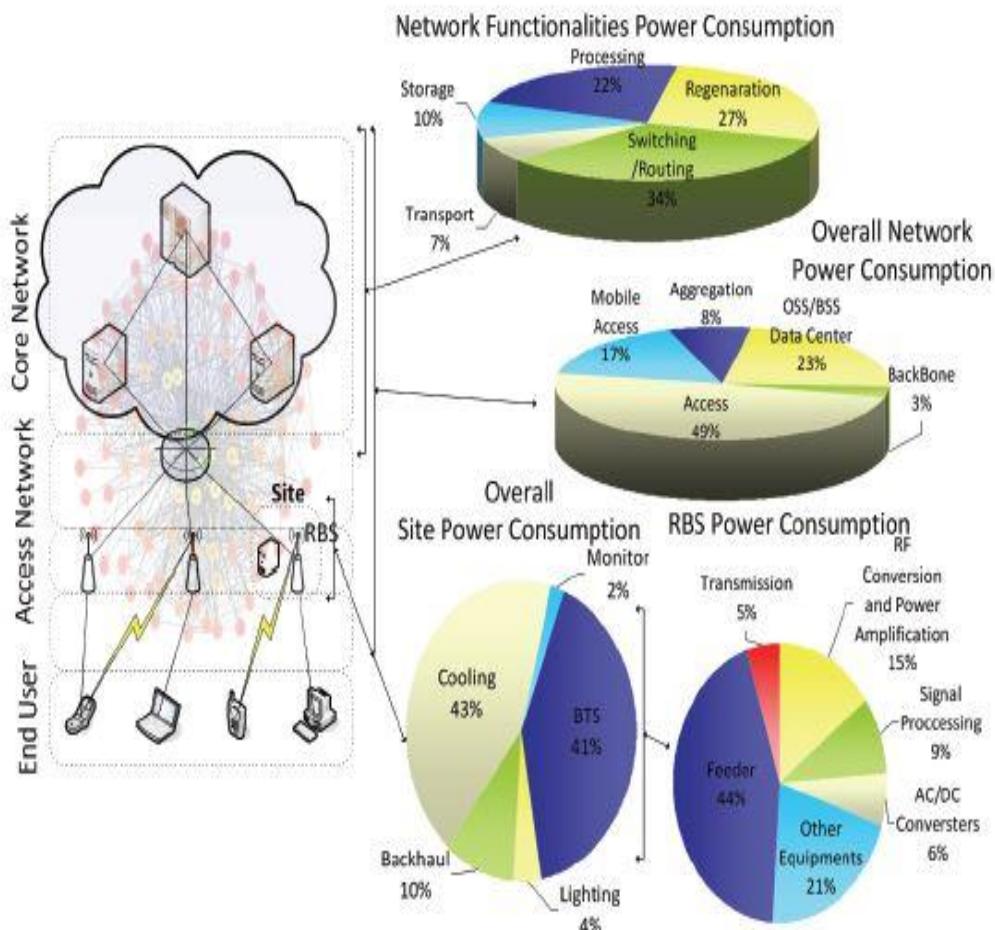
## II. POWER CONSUMPTION IN THE TELECOMMUNICATION NETWORKS

Fig. 4 represents the power consumption of the different sectors of the Information and Communications Technology (ICT) [5]. It is observed that almost 50% of power consumed is due to the operation of the various telecommunication networks, such as the mobile networks, WLANs, LANs and also the fixed-line networks. When it comes to the fixed-line networks, more than 70% of the overall power consumption occurs in the user segment and only about 30% of the power consumption is due to the operator's operational expenditure (OPEX). On the other hand, for mobile networks, about 10% of the overall power consumption corresponds to the usage of cellular network and data by the numerous subscribers, whereas, 90% of power consumption is incurred by the operator's OPEX.



**Fig. 4:  Energy Consumption in ICT Sectors**

Fig. 5 represents how the power consumption is distributed across the different functionalities of the telecommunications network. As far as the overall network performance is concerned, the energy consumption is higher at the access part of the network and the operation of data centers that provides computations, storage of data, applications and data transfer in a network. The main functionalities of a network can be summarized as the process, which consists of regeneration, transportation, storage, routing, switching as well as processing of data.



**Fig. 5:  Power Consumption in different layers of the Telecommunications network**

Both the communication protocols and the electronic devices used, are responsible for the huge consumption of electrical energy and this imposes even further challenges for more sophisticated transportation techniques, removal of thermal energy from the switches as well as the servers and also to have less redundant data transfer.

A characteristic example of energy efficiency in electronic equipments for these functionalities is shown in Table 2.

**Table 2: Power Efficiency of Telecommunication Equipments**

| Equipment | Power Efficiency (Watt/Gbps) |
|---|---|
| Router | 40 |
| IP Switch | 25 |
| Transport TDM | 80 |
| ATM Switch | 80 |

From Fig. 5, it is obvious that the greatest portion of energy is consumed for cooling of the equipments and operation of base station transceivers. On the other hand, monitoring of data and lighting of the telecommunications base stations requires the minimum amount of energy. Within the telecommunications base station, high power demand is due to the feeders, the RF conversion units and the power amplifiers, signal processing units and various other electronic equipments such as air-conditioners and auxiliary equipments, that are being used in the base station transceiver systems.
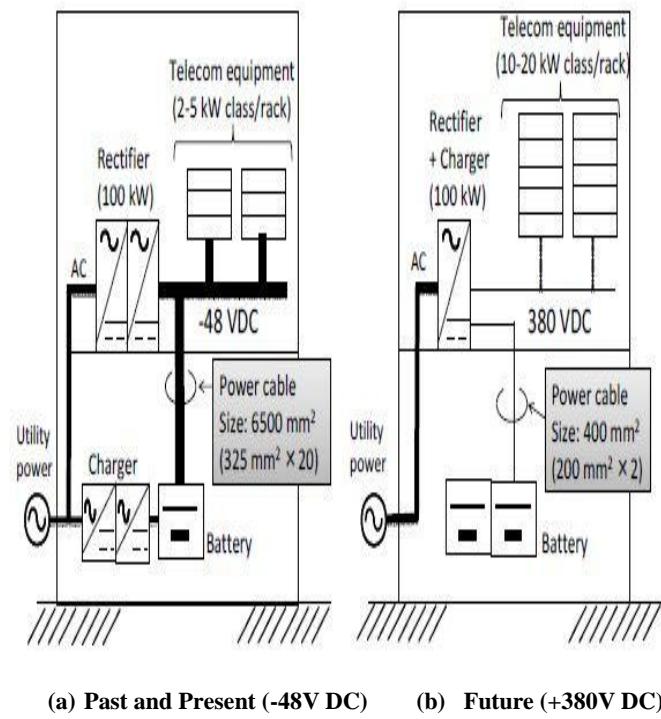
## III. ADVANTAGE OF THE +380V DC POWER DISTRIBUTION SYSTEM OVER THE CONVENTIONAL -48V DC POWER DISTRIBUTION SYSTEM

The data communication equipments have a constant power characteristic, due to the fact that, higher voltage reduces load current. It is found that the load current is inversely proportion to the voltage at the load. Voltage of the +380V DC system is seven times higher than operational voltage of +54V DC (nominal +48V DC system), therefore, the current of the +380V DC system at the same load is reduced to one-seventh times of the original current [6].

In the +380V DC system, voltage drop in the distribution cables by the same ratio as that of the existing -48V DC system results in a theoretical decrease in the cross-sectional area of the conductor by a factor of 49.
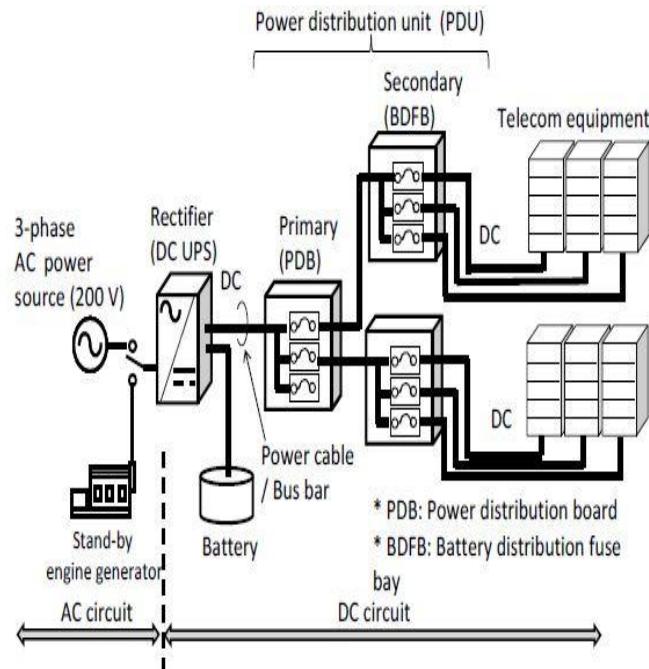
There are benefits not only in the reduction of capital costs of the cables and installation charges, but also in cabling space. Higher DC voltage, in turn, increases the maximum cable length in a telecommunications facility. This is an important factor in the management of battery as well. In general, due to the higher weight of the battery bank for telecommunication applications, it limits the location of battery rooms to the ground floor or basement at the telecommunication sites. Increasing the length of the cable from the battery bank to high-density load centres is a beneficial for site optimization.

Fig. 6 gives an illustration of a typical physical DC power distribution configuration at a telecommunication site and also gives a proposal for the topology of the future. By using the +380V DC topology for powering the high-power density loads, the size of the rectifier and the cable and the costs associated with it can be reduced significantly. Because of the large amount of copper losses associated with the long lines, de-centralized modular rectifiers and valve-regulated lead–acid battery (VRLA) batteries have being deployed close to the powered equipment at many telecommunications sites. In this case, the supply to the -48V DC power conversion equipment is a 3-phase AC, and the -48V DC is distributed only in the telecommunications room, which is in close proximity to the served load [2], [3]. Cable losses are reduced in this case. With many distributed batteries, battery tests and management also present a significant challenge, with increased maintenance cost and reduction in lifetime of the battery. Today, this architecture is no longer flexible enough to power new high-density loads. So, a +380V DC distribution system with centralized batteries provide a more reliable and attractive solution [7].

**(a) Past and Present (-48V DC)     (b) Future (+380V DC)**

**Fig. 6: Simple comparison between a -48V DC and a +380V DC power distribution system**

Fig. 7 shows the most common architecture of the -48V DC power system that is currently being used in almost all the telecommunications sites. This power system consists of rectifiers, storage battery, buses for charging and discharging of batteries, a distribution system along with the DC loads, i.e., the telecommunications equipment. The rated capacities of the rectifier and battery and the cable length depends on the site conditions such as the number of access lines or amount of data traffic due to the huge number of mobile subscribers [8].



**Fig. 7: Typical power distribution system for the telecommunications equipment**

Fig. 8 shows a simplified DC circuit model for comparing the effect of cabling between the -48V and the +380V DC power distribution systems. The length of the cable between each device is given as Distance A, Distance B and Distance C.
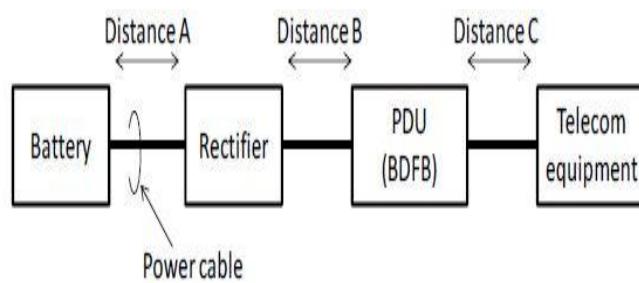
**Fig. 8: Simplified model of the DC circuit used in telecommunications**

Telecommunication carriers in the United States, Japan, and Europe have developed guidelines for voltage drop limits in the DC distribution system. The voltage drop limits were used in the wiring modeling. In Japan, the Indoor Wiring Specifications (IWS) generally specifies drop of 2% or less for the main lines used for low-voltage wiring. In the European Telecommunications Standards Institute (ETSI) standard, the drop is limited to +1V in the -48V wire. For economic reasons, however, the overall voltage drops rate have, however, been specified to about less than 3% when power is supplied from a transformer, less than 5% for long-cable wiring of 120 m or less, less than 6% for cable wiring of 200 metres or less, and about 7% or lesser for cable wiring of over 200 metres. However, because the Japan National Electric Code (JNEC) specifies that the voltage drop rate for a branch circuit should be 1.5% or less, or 2.5% or less when the main line in a distribution system for sensitive electronic equipment is included, a voltage drop rate of about 2.5% is suitable for the distribution lines of the +380V DC power supply system that are currently been proposed for use in ICT applications [9].
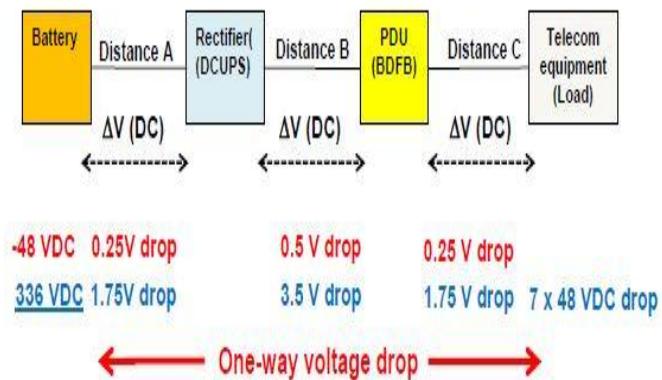


Fig. 9 (a): One-way voltage drop in the United States
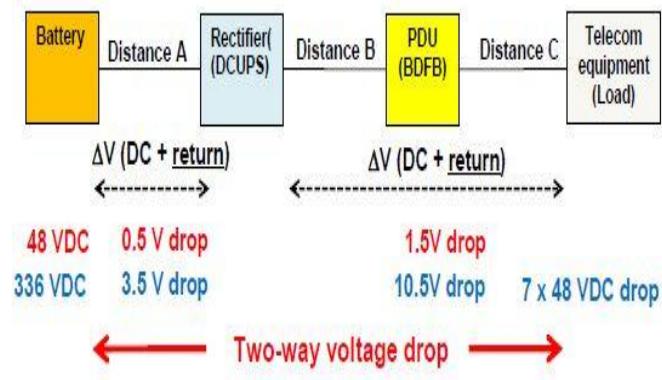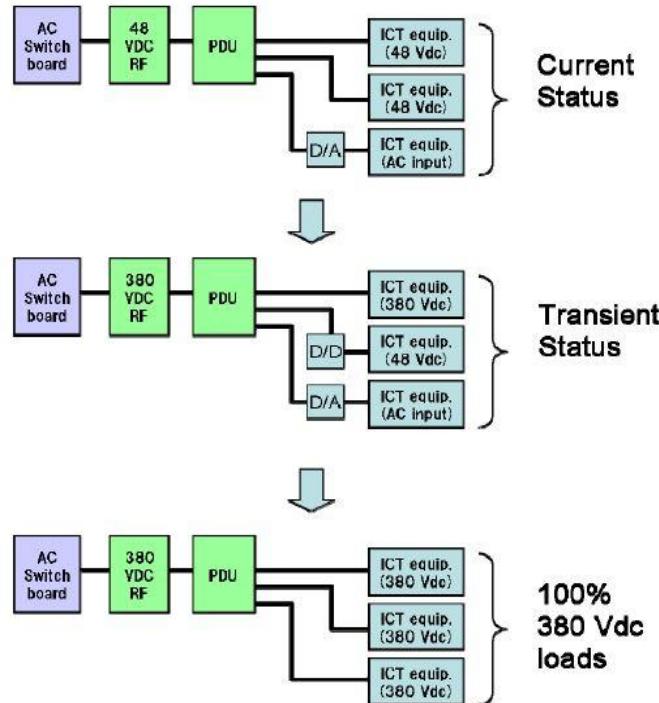


**Fig. 9 (b): Two-way voltage drop in Europe**

The +380V DC architecture permits the installation of a traditional centralized battery without increasing the cost related due to the high copper content in the wirings [10], [11].

The lifetime of the battery used should be increased by strict temperature control in a dedicated battery room and by easier battery management. The cost of maintenance should also be kept down.

Fig. 10 shows the various possible transition paths for the replacement of the currently used -48V DC power system by the +380V DC distribution system at a telecommunications facility [12], [13]. Nowadays, we find many telecommunication companies using mixed -48V DC and AC loads. In most of the telecommunications facilities, the main power supply is -48V DC and inverters are used to convert DC power to AC power for the AC-centric loads. An interim step would be to use +380V DC main distribution and localized +380/-48V DC and +380V DC to AC converters to power the various telecommunication loads. The powered equipments have a specific lifetime and must be replaced over time. The converters can then be removed and pure +380V DC distribution can be applied throughout the entire telecommunications facility. This final configuration with the use of +380V DC gives the highest overall efficiency and the lowest cabling costs.



**Fig. 10: Transition steps for replacement of power systems at the telecommunications site**

The +380V DC distribution wiring have been analyzed for a typical telecommunications facility in terms of costs and other benefits and has been evaluated as an alternative to the existing -48V DC power distribution system. Using the +380V DC as a distribution voltage in telecommunication facilities will dramatically decrease the cross-sectional area of the wiring used compared to -48V DC. It will also lead to a reduction in the obstruction of airflow under the raised floor for the air-conditioning system and will provide more space in the facility. The expansion of ICT the systems have been predicted for the future, especially at the legacy sites or where there are installation space restrictions. This will necessitate a higher voltage distribution system than the currently used -48V DC one. A +380V DC distribution offers significant reduction in wiring cost and also reduces the site cabling costs by more than 90% that of the current cost incurred.

## IV. HIGH-FREQUENCY AC (HFAC) POWER DISTRIBUTION SYSTEM FOR TELECOMMUNICATION SYSTEMS

High-Frequency AC (HFAC) power distribution system was first proposed by NASA for space applications some 45 years ago [14], [15]. The HFAC power distribution approach offers several advantages over the conventional DC power distribution approach, which makes it an attractive solution for many applications such as telecommunications and computers. The main advantage of HFAC power distribution is that the two main conversion steps are eliminated in the overall power distribution architecture [16]. The advantages of HFAC power distribution over conventional DC power distribution is given as:

- It is more efficient
- It is more reliable
- It has better heat distribution
- It has higher power density
- It also has the potential for connector-less power transfer.

Due to the above-mentioned significant advantages of the HFAC power distribution systems over the DC power distribution systems, HFAC power distribution is also being proposed for high-power density telecommunication as well as computer applications [17].

We have already seen that the conventional power distribution in telecommunication systems is based on the DC power distribution. DC power distribution is usually implemented using either the centralized architecture or distributed architecture. One of the main disadvantages of centralized DC power distribution is that due to the distribution of heavy current through the bus-bar, it creates a lot of losses and also requires a large amount of space on the backplane for tracking. Also, remote voltage sensing is required to compensate for the voltage drops along the entire length of the cables. In addition, the heat generated by the DC-DC converters is very high and is mostly concentrated to the converter, which poses a great challenge to the management of thermal energy. Also, few DC-DC converters should also be used to provide redundancy, which can be considered as a necessary evil in the process of communication. Therefore, current sharing is necessary, which also brings complexity to the entire power distribution system [18].

Distributed DC power distribution architecture was introduced to overcome the setbacks due to the centralized DC architecture. This architecture utilizes the point-of-use power supplies (PUPS) in order to locally distribute power to the electronic cards in the telecommunication facility.
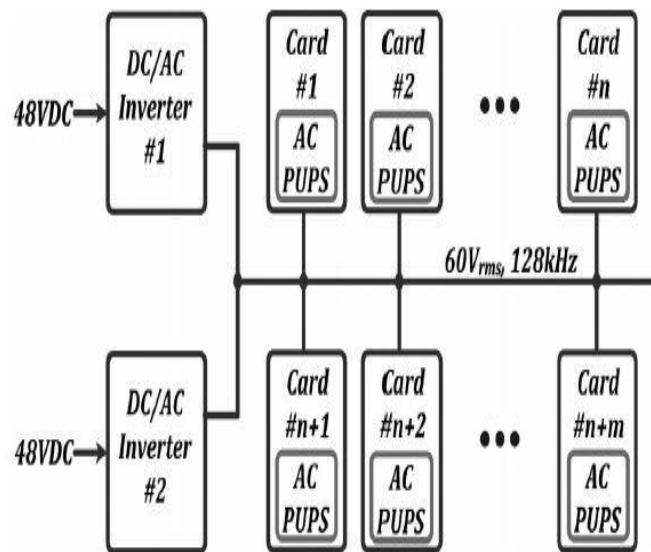
The main advantage of this architecture is that, there is a much more efficient thermal management due to the fact that heat is distributed throughout the entire system.

HFAC power distribution opens up a new horizon for telecommunication systems. The HFAC distribution system not only combines the advantages of DC power distribution, but also offers newer features, which cannot be implemented in the DC power distribution systems alone. The main features of HFAC power distribution are listed as follows:

- It has excellent transient response since there is no low-pass filter (LPF) and HFAC feedback loop.
- The AC power lines can also be used for communication, alarm triggering, etc.
- It has a very simple current limit circuit for the line feed.
- There is simplified insertion of electronic cards.
- It has a simplified ringing generator.
- It also has the potential for connector-less power distribution.

Fig. 11 shows the general block diagram of an HFAC power distribution system for telecommunication systems. In this architecture, there is more than one DC-AC inverter in order to produce an HFAC sine-wave output, which is typically $60V_{rms}$, with a carrier frequency of 128 kHz, from the battery voltage of -48V. Then, the HFAC bus is distributed through the backplane to the electronic cards where AC PUPSs convert it to the required compatible DC voltages [19].

The HFAC bus in telecommunication systems can be of the voltage type or the current type. The advantages of HF sinusoidal voltage distribution are that it has low electro-magnetic interference (EMI) and overall higher efficiency for a wide variety of loads.



**Fig. 11: Schematic of an HFAC Power Distribution**

A hybrid HFAC power distribution architecture was also proposed for the telecommunication systems in order to combine the advantages of both sinusoidal voltage and sinusoidal current distribution [20]. This hybrid HFAC architecture can provide the following features:

- It can be used for connector-less power transfer.
- It has fuse-less protection.
- There is sinusoidal voltage and current distribution.
- It has high overall system efficiency.

In HFAC power distribution for telecommunication systems, several inverter modules are generally configured in parallel to provide reliable power distribution for several reasons, such as better heat dissipation, lower cost, elimination of short-time overload, provision of redundancy, better reliability, and designing of a modular structure. Even sharing of the power results in better thermal management, optimized component ratings, and thus, the overall cost is minimized [21], [22].

## V.  ENERGY EFFICIENCY IN THE TELECOMMUNICATION NETWORKS

Making a telecommunications network to operate in a green manner is a complex task [23], [24]. Sometimes, optimizing energy consumption in one part of the network can increase power consumption in the other part of the network and it degrades the performance of the network as a whole. In general, total network optimization is far better than optimization of individual parts of a telecommunications network. If a network is to work in an energy efficient manner, it is not only for the matter of environmental protection but also for the crucial factor of the deployment of future networks to off-grid areas that rely on Renewable Energy Sources (RES) or sensory networks that rely on battery power supply [25]. Minimizing the power consumption also has a great effect on the reduced cost of operation of the entire network and this makes it more affordable to the subscriber. Network energy efficiency is, however, considered a very complex task as there is no clear solution to the problem [26], [27]. There is always a trade-off between the quality of service, coverage, capacity issues and power consumption. The various observations that have been made, lead to the conclusion that network optimization in terms of energy efficiency can be achieved by providing the following key steps, named as efficiency to network dimensioning, efficiency in network processes, efficiency at the access network, efficient electronic equipments, use of Renewable Energy Sources (RES) and remote-monitoring of the entire network for better management of the radio-frequency or telecommunication equipments as a whole [28], [29].

## VI. CONCLUSIONS

This paper analyzes the benefits of using a +380V DC distribution wiring system for a typical telecommunications site, as an alternative to the existing -48V DC power distribution system. Using the +380V DC as a distribution voltage in the telecommunication facilities will dramatically decrease the cross-sectional area of the conductor wiring compared to -48V DC [30].  It would also lead to the reduction to the obstruction of airflow under the raised floor for the air-conditioning system and will also provide more space in the telecommunications facility. Future expansion of the ICT systems, especially at legacy sites or where there are installation space restrictions, will necessitate a higher voltage distribution system than the currently used -48V DC distribution system. The +380V DC distribution offers significant reduction in wiring cost and reduces site cabling costs by more than 90% of current costs.

This paper also presents a comprehensive review of the HFAC power distribution systems for the telecommunications sector. This paper will serve as a useful reference in the improvement of the existing methodologies and devise a new alternative solution for future High-Frequency AC (HFAC) power distribution systems [31].

The concept of green telecommunication networks was also pointed out. Fixed-line and cellular networks are currently driving their technology towards energy efficient directions. Fiber optics, energy efficient data centers and power management of fixed broadband networks have proven to be an efficient solution, whereas for mobile operators, access networks and base station technology are of utmost importance [32]. The sectors of the network that require the greatest attention are the electronic equipments of both end-user and the access network, thermal energy removal processes, efficient network planning and the telecommunication base station design.

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