# Power Cable Systems Design Evolution in the United States from 1996 to 2020

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## *ABSTRACT*

*Developments in cable designs have always been of great interest to both utilities and manufacturers. In 2003, Joe Dudas, with support from utility bodies (AEIC & NRECA), finished several surveys to establish industry trends in medium voltage (MV) cable. The results of these surveys proved to be very useful to utilities and manufacturers in understanding markets and trends. In 2016 and 2021, the authors undertook two sequential utility surveys respectively on cable, materials, and accessories to all interested parties. These surveys expanded the work conducted by Dudas to a 25-year trend, and thus providing perspective on present day MV cable and accessory usage in the US.*

## *KEYWORDS*

Design, MV, Benchmarking, Extruded Cable Systems.

## INTRODUCTION

Power cable systems have become a ubiquitous feature of modern society. They are responsible for delivering electricity from power stations to homes, businesses, public buildings, and critical infrastructure. They have undergone significant evolution since their inception in the late 19th century, with advances in technology and materials driving improvements in design and performance.

The earliest power cables were made of paper insulation lead-covered and had limited voltage capacity. These cables were mainly used for low-voltage applications, such as lighting and powering small motors. In the decade of 1920, synthetic materials, such as rubber and polyethylene, were introduced as insulation materials. These materials provided higher voltage withstand capability that allowed for improved performance and reliability. The use of synthetic insulation materials was one of the most significant developments in power medium voltage cable system design [1], as it allowed for higher power to be delivered over longer distances, which incentivized their deployment.

In the 1960s, the development of cross-linked polyethylene (XLPE) and Ethelene Propylene Rubber (EPR) insulations marked probably the most significant advancement in power cable technology [1]. This type of insulation provided better thermal and electrical properties than traditional insulation materials, making it suitable for high-voltage transmission. This advancement in insulation technology led to the development of high-voltage power cables, which were used to transmit electricity over longer distances. High-voltage power cables have been critical in providing electricity to remote areas, such as rural communities and offshore oil platforms.

In the 1970s, the introduction of composite materials, such as glass fiber and aramid fibers, as strength components marked a significant improvement in power cable system design. The composite materials provided higher strength and flexibility than traditional ones, allowing for the production of lighter and more durable cables.

In the 1990s, with the advent of digital computers, computer-aided design (CAD) and finite element analysis (FEA) software became prevalent in power cable system design. CAD and FEA software allowed designers to create and test cable designs in a virtual environment, reducing the need for physical testing and generating optimal designs. This approach significantly reduced the cost and time required to develop new cable designs, allowing for faster innovation and commercialization.

In the 21st century, the focus of power cable system design has been on improving efficiency and sustainability. New insulation materials, such as silicone rubber, are been explored, which may offer improved thermal and electrical properties while also being environmentally friendly. The development of renewable energy sources, such as wind and solar, has promoted the development of dc cables for both medium voltage and high voltage applications. They will allow deliver electricity over long distances, e.g. from offshore wind farms to the mainland grid.

Prior work in the area of power cable system design evolution in the USA was initiated by Joe Dudas and supported by the AEIC and NRECA [2]-[7]. The work was aimed to establish industry trends in medium voltage (MV) cable usage. His work started in 1993 [2] with findings reported approximately every 5 years until 2003 [7]. The information collated by Dudas proved to be useful to utilities and manufacturers in understanding technical specification trends and installation practices. The work reported by Dudas only considered cables. With technology evolution and changes in utility operations, the results from the 2003 survey are now likely inaccurate.

Therefore in 2014, the authors launched a baseline project to continue and update the work by Dudas pertaining to Investor Owned Utilities (IOU) and electric cooperatives (co-op) [8]. This paper reports on the next iteration in the NEETRAC's effort to capture the continuing evolution of MV underground cable system construction and usage from 2014.

## APPROACH

### Previous Studies

Prior work in this area was performed by Joe Dudas and supported by AEIC and NRECA [2]-[7] to establish industry trends in medium voltage cable usage (15 kV to 35 kV). His work started in 1993 and updated approximately every 5 years until 2003. Essentially identical questions were asked