

Generations: From Persecution to Innovations in Field Cable Testing

by **Brenda Hite**
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about
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and make
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With over 25 years in the power and energy industry, **Ben Lanz** is currently responsible for IMCORP's technical education and outreach efforts and is the Chairman of the Board for the Power Delivery Intelligence Initiative (PDI2.org), a nonprofit organization dedicated to disseminating T&D best practices. He is a Senior Member of IEEE PES and ICC, and an active or voting member of IEEE DEIS and IAS, American Clean Power, CIGRE, NETA, and a founding member of Electric Power Reliability Alliance. He has served as Chair of IEEE technical committees associated with power system reliability, protection, and testing. He has published dozens of peer reviewed papers and technical conference contributions on the subjects of power system reliability, asset management and diagnostics and is frequently a guest speaker at numerous conferences and seminars.

Have you ever asked yourself "What makes a trailblazer? What prompts a person or company to think far enough outside the box, have a vision beyond the obstacles directly in front of them, and then actually manifest their ideas?" Meet IMCORP founder, Dr. Matthew Mashikian.

Born in Turkey in 1933 to an Armenian family who fled persecution to Lebanon, Mashikian grew up speaking Armenian to his parents, Arabic to childhood friends, French in school, and eventually mastering English at the collegiate level. From an early age, he learned to consider his audience, to overcome challenges and adapt to find success in his surroundings. After graduating from high school in 1950, he remained in Beirut and taught high school math for three years to help support his family. Mashikian went on from teaching to complete his Bachelor of Engineering degree at the

American University of Beirut.

Both Dr. Mashikian and his future German wife's families fled persecution in their home countries, and through a series of moves and events they met in the early 1960s while he waited for a United States work visa and worked in Sweden for ASEA (the 'A' in modern day ABB) as a surge arrester application engineer. Eventually they both immigrated to the United States and settled in Michigan where Mashikian met up with the rest of his family and worked for Detroit Edison (modern day DTE) for sixteen years.

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While at Detroit Edison, Mashikian developed patents in the areas of arresters, cable accessories, batteries, and electric vehicles, and helped support the development of the Electric Power Research Institute (EPRI), through which he collaborated with many professionals in the industry. During that time, he also went to school nights to earn his master's degree (Wayne State University), get his professional engineering license, and receive a Doctor of Engineering degree (University of Detroit) in electrical engineering.

Mashikian at Detroit Edison in early 1970s

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At Detroit Edison's research lab, he had the opportunity to experiment with different types of tests and assess their benefits and limitations. In 1963, the research team tested a sample of a newly developed extruded dielectric cable, which was insulated with polyethylene but also had carbon-impregnated fabric tape shielding over the conductor and insulation. Mashikian knew they needed to be rigorous in their testing if the new cable design was going to be successful in its application. The initial 60 Hz breakdown voltage of the newly developed cable exceeded 200 kV (conversely, the existing rubber-insulated, lead-covered cables withstood only around 35 kV). Unfortunately, after subjecting the cable sample to 3 or 4 load cycles (cyclically heating and cooling the

fabricated with extruded shields. The Detroit Edison research team developed a rigorous acceptance test that included cyclic heating and cooling while the cables were immersed in water and subjected to moderately elevated voltage. As a result, only four manufacturers were qualified as suppliers to the company. By 1966, Mashikian and his colleagues wrote a report

Science. Among his accomplishments was the development of a patented technology capable of detecting defects in underground utility distribution cables. By this time, PD testing was the standard for all cable and accessory factory quality control. In 1985, when utilities funding the work at the EIRC continued to express their need to find a better way to measure cable system reliability in

By 1966, Mashikian and his colleagues wrote a report recommending improvements that led the manufacturer to develop extruded semiconducting insulation layers. Extruded semicon layers are now standard in all modern medium and high voltage cable designs.



Mashikian, center, preparing a test circa 1969 at the Detroit Edison R&D lab

cable to room temperature), the cable breakdown voltage dropped drastically to less than 50 kV. The team established the reason for this breakdown by testing the cable with a modified WW2 radio to detect partial discharge. They found that cyclic heating and cooling produced gaps between the conductor, the metallic shield and the insulation, causing rapid deterioration by partial discharge. Their report recommended the use of extruded semi-conducting shields. Subsequently, twelve cable manufacturers submitted samples

recommending improvements that led the manufacturer to develop extruded semiconducting insulation layers. Extruded semicon layers are now standard in all modern medium and high voltage cable designs.

While doing some freelance consulting, Mashikian was recruited by the University of Connecticut (UConn), where he worked into the 1990s as a full professor of Electrical Engineering and the Director of the Electrical Insulation Research Center (EIRC) of the Institute of Materials

the field, he went to work, developing a proposal and recruiting professors with expertise in analog hardware, digital signal processing, traveling waves, and antennas. In 1989, after some initial research, Mashikian invited a top industry PD expert to review the team's progress and provide an independent review. The expert concluded, "What you are doing here is impossible," believing the background electromagnetic noise would be impossible to overcome in the field. Mashikian thanked the consultant for the review but was not deterred. By the next year, the team was performing rudimentary PD tests in the field and locating defects. Mashikian felt this innovative technology, which he and the UCONN team had developed over the course of a decade, had great commercial potential because it pinpointed the precise location of problem spots in cable systems without collateral damage, enabling companies to repair small sections of the line rather than replace the entire cable.

Among his accomplishments was the development of a patented technology capable of detecting defects in underground utility distribution cables.



In 1995, while most of his peers were looking to retire, Mashikian, aged 62, founded IMCORP with the intent to use his skills to better the industry. Between 1996 and 2000, Mashikian identified several engineers at the University of Connecticut and others from the industry to work with him and advance his vision to develop a test comparable to the standardized cable and accessory manufacturer quality control tests – an offline test utilizing a 50 or 60 Hz voltage source to produce a 30-second overvoltage and a measurement system with the ability to remove background noise in order to detect and locate PD in cable systems down to 5 picoCoulombs (pC) (standardized test parameters in Table 1).

Utility representatives witnessing prototype test on Mashikian's home driveway circa 1989



Field testing on Pikes Peak, CO with primitive equipment in 1996

Table 1. Standardized PD Test Specifications

Cable Component Standard	Thresholds (50/60 Hz only)
IEEE 48 Terminations	No PD >5 pC up to 1.5 U _o
IEEE 404 Joints	
IEEE 386 Separable Connectors	No PD >5 pC up to 1.3 U _o
ICEA S-97-682 / 94-649 Cable 5 kV-46 kV	No PD >5 pC up to 4 U _o
ICEA S-108-720 Cable 69 kV-500 kV	No PD >5 pC up to 2 U _o
IEC 60502 Cable & Accessories 6 kV-30 kV	No PD >10 pC up to 1.73 U _o
IEC 60840 Cable & Accessories >30 kV-150 kV	
IEC 62067 Cable & Accessories >150 kV-500 kV	

U_o is operating line to ground voltage, picoCoulomb (pC)
 4U_o is an estimate, actually 7.9 kV/mm or 200 V/mil
 IEC 60840/62067 Accessories have a 5 pC requirement

In 1996, Mashikian and his team performed the first commercial field tests: one for Northern Indiana Public Service Company (NIPSCO) and another for Colorado Springs Utilities (CSU). The CSU tests included the aged cable feeding the station atop the 4k+ meter (14kft+) Pikes Peak, finding the costly cable system was in good condition and did not need replacement. The tests at NIPSCO demonstrated the technology could easily find defective splices and even narrowed the selection of defective components to the worst three. The utility called Mashikian within a few weeks and said one of the three worst performing splices failed and they wanted additional testing services. Through 1997 and 1998, Mashikian and his team performed tests at Xcel Energy in Denver, Florida Power and Light (FPL) in Florida, and what is now Hydro One in Canada.

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In 2000, FPL and Mashikian's team developed a pilot to assess 46,000 meters (150,000 feet) of buried cable systems and track the performance over the course of eight years. During those eight years, the team repeatedly tested cable systems, measured specific defect location degradation rates, and extracted samples to research failure mechanisms. The results revealed previously misunderstood delay mechanisms in cable system defect degradation and proved the predictive power of using standardized partial discharge measurements on aged cables.

During the 2000s, significant testing programs were implemented at FPL, NIPSCO, Xcel Energy and a few other utilities on hundreds of miles of cable systems with the primary purpose of assessing aged assets and optimizing repair and replacement activities. Through many challenges, technology steadily improved and, by the mid 2000s, over 95% of field assessments were achieving factory-level sensitivity (see standards table).

In the early 2000s, We Energies asked Mashikian's team to demonstrate their field diagnostic technology and compared it to the other technologies available. The technology proved to be the most reliable and was quickly adopted to commission all new feeder cable systems for We Energies. During this time, We Energies' feedback to accessory manufacturers helped improve product performance and for the first time, field PD testing was helping industry advance product technology with a level of precision never seen before.

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In the mid-2000s, FPL was struggling with what was thought at the time to be the largest wind farm in the world. A 300 MW wind site in Washington state was having numerous cable system failures costing on average \$100,000 per outage due to lost revenues. FPL remembered the success achieved when applying PD testing to their aged cable systems and asked IMCORP if they had the capability to test new cables at wind sites. As part of a larger investigative team, IMCORP helped identify multiple issues, including overheating splices, cable manufacturing defects, termination and splice workmanship issues, and installation damage. From that experience, many engineers and technicians learned the power of using partial discharge testing to commission and identify workmanship and application problems. In fact, partial discharge testing has been so successful in eliminating significant revenue loss due to cable failure that more than 60% of wind and solar projects in North America currently specify standardized PD testing (Table 1).

By the late 2000s, several utilities were interested in using partial discharge testing to optimize repair and replacement programs, but one significant challenge still existed: the stock price of investor-owned utilities in North America is penalized when the utilities spend additional money on operating and maintenance tasks. However, in 2009, the Federal Energy Regulatory Commission (FERC) ruled the cable assessment cost may be capitalized because it enables utilities to achieve like-new performance and extend the useful life of aged cables. Within a few years, utilities like Duke Energy, Southern California Edison and Centerpoint developed large scale testing programs testing tens of thousands of cable systems, each achieving dramatic reliability improvements at significantly lower costs. Even with these achievements, Mashikian did not stop innovating. Mashikian, who is now in his 80s, has continued to push his R&D team to advance the technology to develop additional patents in the last few years. Some of these advancements include

automated analysis with AI and machine learning techniques and scaling the technology to fit in small vans with Lithium-ion battery power and super lightweight air-core transformer technology.

Today, the technology has been applied to 300 million feet of cable systems rated 5 to 500 kV in over 17 countries and 49 of the United States. Over the past two decades, utilities have used standardized PD testing services to save hundreds of millions of dollars by deferring asset replacement. Similarly, critical power and industrial facilities have saved hundreds of millions in avoided outages by commissioning their cable systems and eliminating installation errors with a standardized PD test (offline 50/60 Hz PD test with 5 pC sensitivity). In addition to the direct testing benefit, the industry has benefited from the knowledge derived from what is most likely the largest database of PD tested cable systems and service performance in the world. The database, coupled with over 8,000 defect dissections, has created a knowledgebase that has helped advance the development of cable system components with many of the large manufacturers and has initiated numerous best practices for testing and operations that can easily double the useful life of cable systems.

Stories about trailblazers who change an industry and make significant contributions to technology to better humanity are seldom simple. Mashikian's story is no exception. Mashikian's diverse life experience, unquenchable curiosity and passion for research and technical excellence, and ultimately the drive to make the world a better place, has paved the way for the next generation. In the second age of electrification, it is an exciting time to be in the electric power industry. There are numerous opportunities for the men and women of this generation to take what the Mashikians of the world have given us and make a positive impact on humanity. How are you going to use your expertise to leave your mark?



*Mashikian and university team 1996
Early IMCORP Days*

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