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Award of the Edison Medal to Doctor Arthur Edwin Kennelly

CITATION by CLAYTON H. SHARP

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The body of science and technology on which electrical engineering is based is the work of many men of diverse talents. There have been experimental physicists, theoretical physicists, mathematicians, inventors and finally engineers who, taking the mass of experimental facts, of substantiated theory and of successful inventions, have leavened it with their own practical knowledge, experience and resourcefulness and have produced the huge and useful structure which is the electrical industry of today. Most of the workers in this science have been capable of classification in one or more of the above groups. However certain ones, by the versatility of their genius, defy classification. They take a high place in the hierarchy of pure scientists. As mathematicians they are not plodders, they are originators. Withall, they are, in the highest sense of the term, practical men; inventors and engineers. The chief of this group was Lord Kelvin. It is to this group that Doctor Arthur Edwin Kennelly belongs.

Like another illustrious member of the group, Professor Elihu Thomson, Doctor Kennelly is of British parentage. He was born in India and educated in England, Scotland, France and Belgium. His first position was that of assistant secretary of the Society of Telegraph Engineers of London, now the IEE. In 1876 he joined the Eastern Telegraph

Company, thus entering into the most highly developed electrical field of that time. He was promoted steadily until in 1886 he became senior ship electrician on submarine cables, a position which made severe demands on the technical knowledge and resourcefulness of the occupant. It is reasonable to infer that his familiarity so gained with the theory and practice of the transmission of signals over long lines with distributed capacity formed the basis for his future work in the field of telephony and in the mathematical treatment of the phenomena of transmission lines.

He came to America in 1887 and became the principal electrical assistant to Mr. Thomas A. Edison, which position he held until 1894. These years, in a hard and intensely practical school could not have been other than instructive and stimulating to a young engineer. In 1893 he was, in addition, consulting electrician to the Edison General Electric Company now the General Electric Company of New York, which is good enough evidence of the success of his work with Mr. Edison.

In 1902 he was appointed Professor of Electrical Engineering at Harvard University and occupied that chair until his retirement as Professor Emeritus in 1930. During the years 1913 to 1924 he was also Professor of Electrical Engineering at the Massachusetts Institute of Technology and is now Professor Emeritus of that institution also. During some years of his active service at the MIT he was director of electrical engineering research and Chairman of the Faculty.

With all these duties and responsibilities Doctor Kennelly has nevertheless found time and energy to engage in many out-

side activities. He has served two terms as President of the AIEE. He was President of the Illuminating Engineering Society during the early days of that organization when his guidance was particularly valuable. He has been President of the Institute of Radio Engineers, of the Metric Association, and of the Union Radio Scientifique Internationale. He is Honorary Secretary of the United States National Committee of the International Electrotechnical Commission.

In the international field his services have been of unusual distinction. He was a United States delegate to The Electrical Congresses of 1900, of 1904, where he carried out the onerous duties of General Secretary, and of 1932; also to international radio conferences in Paris in 1921 and in Washington in 1927 where international allocations of radio transmission frequencies were made. He is a member of the International Committee on Weights and Measures, the last meeting of which at Sevres in 1933 Doctor Kennelly attended. During the year 1921-1922 he represented seven cooperating American universities as first exchange professor in engineering and applied science at several French universities. In 1931 he gave a series of lectures in Japan under the Iwadare Foundation. He has published many books and is the author of more than 350 papers, many of which were presented before scientific organizations at home and abroad. Without stint he has given of his time in committee work in accomplishments for which he has neither desired nor received personal credit. At the present time he is Chairman of the Committee on Electrical Definitions which has already accomplished an important work.

Doctor Kennelly joined the AIEE as an Associate in 1888. In 1894 he had already become a Manager, having among his colleagues in that office Pupin, Steinmetz, Ryan and Carty. He was also chairman of the only technical standing committee of the Institute namely the Committee on Units and Standards. The committee was wrestling with the question of the names of the magnetic units. Forty years later, we find Doctor Kennelly chairman of the Advisory Committee of the International Electrotechnical Commission which is laboring on the same subject. Doctor Kennelly has been at the fore-front of all the discussions of all the intervening years. At the Paris Congress of 1901 it was Kennelley who delivered the vote of the United States. We expect that he will succeed in his task of getting complete international accord, for in power of reasoning and persuasion he is unexcelled. This is only one instance. For forty-five years the Transactions of the Institute have been enriched by his contributions of papers and discussions.

One of these contributions, which is now a classic, demands further consideration even in as brief a review as can be made in the time now allotted to us. In April 1893 Doctor Kennelly presented a paper under the title "Impedance" in which he gave the first application ever to be made of complex quantities to technology, and to the extension of Ohm's law to alternating circuits. In the paper he first showed that in a circuit containing resistance and inductance, the impedance is given by the hypothenuse of a right triangle, the other sides of which are the resistance and a quantity

which he called the "inducatance-speed", namely the inductance multiplied by $2\pi$ times the frequency. He said: "The impedance is therefore the geometrical or vector sum of the resistance and inductance-speed, when these are plotted on two rectangular axes. Calling this impedance i, Ohm's law gives

$$c = \frac{e}{i} \qquad e = ic \qquad i = \frac{e}{c}$$

corresponding to the usual formulas for continuous currents".

The paper went on to show how the impedance of reactors in series is given by the vector sum of their individual impedances; how the impedance triangle of a resistance in series with a condenser is drawn, taking the reciprocal of the "capacity-speed" of the condenser as the vertical side of the triangle and turning it downwards; how problems of resistance and reactances in multiple may be solved by vector methods.

Finally Doctor Kennelly enunciated the following general law.

"Any combination of resistances, non-ferric inductances, and capacities, carrying harmonically alternating currents, may be treated by the rules of unvarying currents, if the inductances are considered as resistances of the form $pl\sqrt{-1}$, and the capacities as resistances of the form $-\frac{1}{kp}\sqrt{-1}$, the algebraic operations being then performed according to the laws controlling 'complex quantities'."

How completely novel the method and the ideas set forth in the paper were is indicated by the fact that the members called upon to discuss it, and they included some who were already famous in the profession, at least one of whom later

became an Edison medallist, expressed their appreciation of it but declined to make further comment on the ground that they had not had time to digest it. Yet, today, how simple and commonplace it all seems!

However, Doctor Steinmetz, who had not been present at the meeting, sent in a written discussion after adjournment, from which it is seen that his keen mind had instantly grasped the full significance of Doctor Kennelly's disclosure. He wrote, after quoting the general rule which is given above, and emphasizing its significance:

"It is well known that the points of a plane can be represented by complex quantities in their rectangular representation .a + bj, or their polar representation $r(\cos \phi + j \sin \phi)$, and use has been made hereof repeatedly in the mathematical treatment of vector quantities. It is, however, the first instance here, so far as I know, that attention is drawn by Mr. Kennelly to the correspondence between the electrical term "impedance" and the complex numbers".

"The importance hereof lies in the following:- The analysis of the complex plane is very well worked out, hence by reducing the electrical problems to the analysis of complex quantities they are brought within the scope of a known and well understood science".

Doctor Steinmetz's subsequent development and use of the method in his many published works have been largely responsible for the familiarity which we have with it today; so much so that the credit for the original idea is sometimes given to him. It is interesting on this occasion to note that this whole matter was one of the results of the work which Doctor

Kennelly did while associated with Mr. Edison.

In April 1895 Doctor Kennelly, in collaboration with Professor Houston, presented the first of his many papers employing complex angles in dealing with transmission line problems.

The thing for which Doctor Kennelly is best known is undoubtedly his explanation of the mechanism of the transmission of radio waves. In the beginnings of radio telegraphy it was supposed, most reasonably, that radio transmission to any great distance was practically hopeless, both on account of the curvature of the earth's surface and because with the field strength varying inversely as the square of the distance, the energy would be attenuated very rapidly. Marconi's audacity in putting this idea to the test in his famous Cornwall to Newfoundland experiment, proved that this was not so. Evidently some unknown factor intervened to change the conditions. To explain this it might be supposed that there exists high up in the earth's atmosphere, a conducting region or layer by which the radio waves are deflected and turned back towards the earth, so that the curvature is overcome and the energy spread restricted to two dimensions. Thus the attenuation of signals would vary with the first power of the distance instead of the square. Doctor Kennelly not only did this but he went much further.

His publication of the matter in the number of the Electrical World and Engineer for March 15, 1902 had the significant title "On the Elevation of the Electrically-Conducting Strata of the Earth's Atmosphere". In this article he did not assume the existence of purely speculative conducting strata

but, basing his calculations on data of J.J. Thomson's, he showed that electrically conducting strata must exist because of the rarefaction of the atmosphere, at a height of the order of 50 miles, with a conductivity several times as great as that of sea water. The presence of such strata being thus assured from independent consideration, the explanation of long-distance radio transmission followed at once and was given with precision and clearness and for the first time.

Doctor Kennelly is noted for his accuracy of statement. If he cites a numerical value which is not exact even unto to the third and fourth generation of decimals, he calls it an approximate value. He never leaves the reader in doubt as to what units he is employing. He has introduced a simple system of prefixes: "ab" for the absolute magnetic system and "stat" for the absolute electrostatic system.

He has been endeavoring for years, chiefly through the International Electrotechnical Commission, to get an agreement on an absolute practical system of units which should include the mechanical as well as the electrical units. The prospects for success have become much brighter during the past year.

In conferences and in committee work his urge is always to get something tangible done, something agreed to. An imperfect agreement is better than no agreement, for at least it records progress made and can later be amended. He never attempts to force his own views on his colleagues. Stubborness and pride of opinion or of parentage are foreign to his nature. He sees his adversary's point of view as well as his own, and

is always fair, judicial and tolerant. The combination of these characteristics with a complete mastery of his subject accounts for the large measure of success which his work in these directions has achieved.

We, who have been his associates for many years, have known the modesty of his deportment, the geniality of his personality, the transparent honesty of his nature and the loyalty of his friendship. We have, perhaps, been too close to him to realize readily what his stature is amongst his contemporaries. The many scientists and engineers in foreign lands who know him personally and through his writings have, at their distance, been in a more favorable position. Thus, while he is an Honorary Member of this Institute, he is an Honorary Member of the Institution of Electrical Engineers of London, of the Societe Francaise des Electriciens, of the Elektrotechnischer Verein and of the Institute of Electrical Engineers of Japan. He is a Corresponding Member of the British Association for the Advancement of Science and a Fellow of the Royal Astronomical Society.

His affiliations at home are not confined to engineering organizations. He is a Member of the National Academy of Sciences, of the American Philsophical Society, of the American Mathematical Society, of the American Physical Society, and of the American Association for the Advancement of Science. He is a Fellow of the American Academy of Arts and Sciences.

This is not the first occasion on which Doctor Kennelly has received an award. As a young man, in 1887, he received the Institution Premium from the Institution of Electrical Engineers, and in 1889 he received the Fahie Premium from the

same body. The Franklin Institute of Philadelphia granted him the Longstreth silver medal in 1916 and the Howard Potts gold medal in 1917. He was the recipient of the Volta medal in 1927 and the gold medal of the Institute of Radio Engineers in 1932. The French Government has conferred on him the Cross of the Legion of Honor.

In the list of distinguished engineers on whom the American Institute of Electrical Engineers has conferred the Edison Medal, the highest honor which it can bestow, none has been more worthy than Doctor Arthur Edwin Kennelly.

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