Measurements in Power Systems: The Activity of IMS TC-39

Carlo Muscas

The increasing calls for decarbonization, and the consequent need for the energy system to integrate ever-increasing shares of renewable energy, place the electric grid at the core of an integrated, decarbonized energy system. This calls for Transmission System Operators (TSOs) and Distribution System Operators (DSOs) to fast-track the integration of clean energy solutions into the electric grid [1]–[3]. In this framework, whatever new management/business models can be envisaged for modern electric power systems, they must be based on the availability of suitable information. Consequently, the continuous evolution of applications in power grids stresses the need to define, develop, implement, and qualify innovative measurement components, devices, and systems for proper, effective, and efficient implementation of enhanced monitoring and control applications in electric transmission [1] and distribution [4] networks.

On this basis, the Technical Committee TC-39 of the IEEE Instrumentation and Measurement Society (IMS), "Measurements in Power Systems," was created about one decade ago to gather people involved in the field of power system measurements, in order to pursuing the following goals: leading the research on specific topics, encouraging the research on challenging topics, promoting and facilitating the exchange of knowledge between scientists, organizing events, becoming an official consultative body for industries and operators in the field of power systems, as far as the design and development of specific instrumentation is concerned, and, last but not least, promoting and disclosing new standards and guidelines. The current TC roster is composed by 26 members, from 13 countries.

The work performed by the TC members during the years, which is also witnessed by several contributions published in this Magazine ([5]–[12]), led TC-39 to receive, in 2016, the "Outstanding TC Award" from the IEEE Instrumentation and Measurement Society. In the following, the main activities of this technical committee will be summarized, by mainly focusing, rather than on specific research topics, on three important general aspects: the driving idea to stimulate and promote scientific and technical innovation in the field of measurements applied to power systems, through a specific specialized forum dedicated to these subjects; the will to create a shared community with researchers and practitioners operating in the world of power system, to exchange knowledge, expertise, and ideas; the need to develop new standards on specific topics of interest for companies and operators working in the field of power system instrumentation and measurement.

Fostering Scientific and Technical Innovation

The main activity of IMS TC-39 is certainly represented by the organization of the IEEE International Workshop on Applied Measurements for Power Systems (IEEE AMPS). The workshop deals with all the aspects related to measurement applications in current power systems and in future grids and has the main goal of encouraging discussion among experts coming from academia, industry and utilities.

The event has been held yearly since 2010. The first seven editions were hosted in Aachen, Germany. Then, it moved to Liverpool, UK, and Bologna, Italy. For the 10th anniversary, the workshop came back to its original venue, in Aachen. Independently of the venue, the peculiar characteristic of the AMPS workshop is represented by the animated and fruitful discussions that always follow each presentation. Fig. 1, Fig. 2 and Fig. 3 show some pictures taken from the different workshop editions. The eleventh edition, planned for 2020, was postponed to 2021 due to the COVID-19 pandemic, and was held as a virtual event in September 2021 (https://amps2021.ieee-ims.org/).

During the years of its successful history, the subjects around which AMPS is built have been continuously updated, to take into account the changing scenarios in the modern power systems, with new challenging aspects to be considered in monitoring, managing, and controlling both the power grid and several of its components (generators, lines, transformers, converters, loads, etc.). At the beginning, the original topics where mainly represented by the design and characterization of innovative transducers, the definition and measurements of non-sinusoidal quantities, the power quality issues, etc. These

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Fig. 1. A presentation during the 8th edition of the IEEE International Workshop on Applied Measurements for Power Systems (Sensor City, Liverpool, UK, September 2017).

topics have been consolidated during the years, but they have been also accompanied by new subjects, like the ones related to the smart management of the electric grids in the presence of renewable energy sources and electric vehicles and to the wide diffusion of distributed synchronized measurement systems (Phasor Measurement Units, smart energy meters, ICT infrastructure, advanced signal processing tools, etc.) along with their applications (e.g., state estimation and fault location).

The cruciality of these topics in modern electric power systems is confirmed by the continuous growing interest toward the AMPS workshop: in the last edition, the number of submitted papers was almost double with respect to the beginning, with proposed contributions coming from 50 different affiliations belonging to 18 countries in six continents.

Another important feature that has always characterized the IEEE AMPS workshop, made possible thanks to the

Fig. 2. A presentation during the 9th edition of the IEEE International Workshop on Applied Measurements for Power Systems (University of Bologna, Italy, September 2018).

Fig. 3. Opening session of the 10th edition of the IEEE International Workshop on Applied Measurements for Power Systems (E.ON Energy Research Center, RWTH Aachen University, Germany, September 2019).

support of the Editors in-Chief and the editorial staff of the *IEEE Transactions on Instrumentation and Measurement* (TIM), is represented by the possibility for the authors to submit technically extended versions of their papers to dedicated Special Issues to be published in the TIM. The papers accepted for publication, selected after a thorough peer review process, have often shown a significant impact in the scientific community, as confirmed by the fact that they commonly receive a higher number of citations, with respect to the entire set of papers published in the TIM in the same year (Fig. 4).

TC members in the organization of the IEEE International Conference on Smart Grid Synchronized Measurements and Analytics (IEEE SGSMA).

The first edition of this conference, which was technically sponsored by IEEE Power and Energy Society (PES), was held in College Station, Texas (USA) in May 2019. It was a successful opportunity for exchanging ideas and expertise between leading researchers, developers, and practitioners from academia, research, and industry from all over the world.

Sharing the Culture of Measurements in the Power System Community

Since its origin, one of the main goals of TC-39 has been to build a bridge between the instrumentation and measurement community and the much wider power system community, where measurements are the basis for any management, control, and protection strategy. In this connection, an important recent achievement has been the involvement of

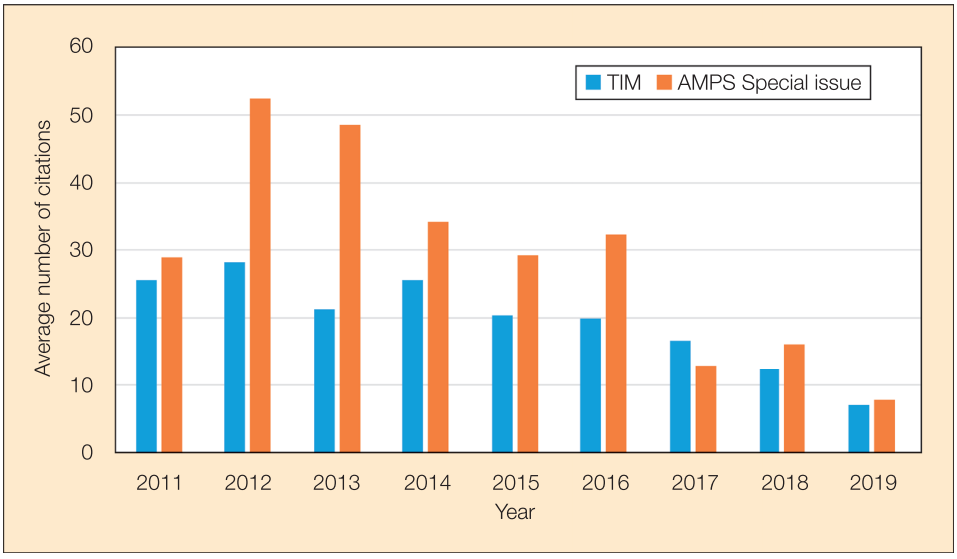

Fig. 4. Impact of the papers published in the IEEE AMPS Special Issues of the *IEEE Transactions on Instrumentation and Measurement* (TIM) (elaborated by the author based on data taken from Scopus database).

The 2021 edition of IEEE SGSMA was planned to be held May 25-27, 2021 in Split, Croatia. Due to COVID 19 pandemic, the organizers decided to move the conference to 2022. It will be held May 24-26, 2022 in Split, Croatia (https://www.sgsma2022.org/). It was also decided to hold a special SGSMA 2021 event on May 25-27, 2021, that featured only webinars, panels, tutorials and invited keynote presentations (https://www.sgsma2021.org/). An important novelty of these new editions is that now SGSMA is technically co-sponsored by the IEEE Instrumentation and Measurement Society, with the substantial contribution of TC-39.

The themes of the presentations that were given at SGSMA 2021, in their different forms, covered all aspects of synchronized measurements: traceability, clock synchronization, data-driven analytics, state estimation, point on wave monitoring, EdgePMU, harmonic synchrophasors, wide area monitoring protection and control, analysis of synchrophasor data through machine learning and artificial intelligence, with applications designed for both transmission and distribution grids, etc. In several of these events, researchers from IMS, and in particular from TC-39, were involved.

Particularly interesting, for the practical perspectives of these topics, were the panels dealing with international experiences in synchrophasor applications, with contributions coming from all over the world, ranging from North-America to South-America, from European Nordic countries to Romania, from Russia to China, from India to South-Africa.

The IEEE SGSMA 2021 event thus provided a leading forum for disseminating the latest research in synchronized measurements and analytics, to facilitate innovation, knowledge transfer and the technical progress in addressing synchronized measurements and analytics to advance smart grids.

Standardizing Test and Measurement Activities

As any technical committee in IEEE Instrumentation and Measurement Society, IMS TC-39 is committed to developing standards and guidelines, according to the policies defined by the IEEE Standard Association.

In particular, driven by the increasing request coming from instrumentation manufacturing industry and test laboratories, in the last years the effort has been focused on the evaluation of uncertainty in the calibration of Instrument Transformers (ITs). A Joint Working Group has been created together with technical committee TC-38 "Instrument transformers" of the International Electrotechnical Commission (IEC), which is in charge of releasing an entire series of documents dedicated to ITs (IEC 61869 series), to define a dual-logo document on this specific subject. The outcome is represented by Technical Specification IEEE/IEC 61869-105 "Uncertainty evaluation in the calibration of Instrument Transformers," which, at the moment of writing this report, is undergoing its final revision and is thus expected to be released in the second half of 2021.

This part of IEC 61869 establishes a common viewpoint of the evaluation of uncertainty in calibration and its application in testing of ITs used for a.c. (in the frequency range 15 Hz – 3 kHz), covering low voltage as well as high voltage. It covers the uncertainty evaluation in calibration of ITs independently of the technology used (either inductive or non-inductive ITs) with both analogue and digital output format. The document reports how to take into account the sources of uncertainty of the calibration set-up and how to combine their effects in order to evaluate the uncertainty in the calibration results. More in detail, firstly the sources of uncertainty in the calibration setup are identified, including reference IT, comparator, burden voltage/current sources, and others. Then, digital processing methods to evaluate IT errors with digital comparators are described, considering the situations where the device under test and the reference IT have either analog or digital outputs. Finally, the document presents the test procedures to be used for assessing the accuracy of ITs, by including the possibility of performing on-site calibration of an IT.

Conclusions

The significant changes that are occurring in the electric power systems are driving the work of researchers and practitioners toward new measurement solutions with unprecedented functionalities and performance. This report summarizes the activity of technical committee TC-39 "Measurements in Power Systems" of the IEEE IMS, aimed at creating a stimulating scientific environment where the fundamentals, the development, the implementation, and the characterization of such innovative proposals are presented, discussed, and shared. To meet these goals, TC-39 will be glad to welcome new interested volunteers. Please visit https://ieee-ims.org/technical-committee/tc-39 for more information.

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Carlo Muscas (M'98-SM'15) is Full Professor of electrical and electronic measurement at University of Cagliari, Italy. His current research interests include the measurement of synchronized phasors, the implementation of distributed measurement systems for a modern electric grid, and the study of power quality phenomena. Prof. Muscas is currently the Chairman of the TC-39 "Measurements in Power Systems" of the IEEE Instrumentation and Measurement Society and an Associate Editor for the *IEEE Transactions on Instrumentation and Measurement*.