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The Special Reporters ask whether electricity networks with more converter technologies represent an increased risk of "the impact of GICs in addition to other known impacts?" On the contrary, we think that converter technologies may mitigate the risks. To understand how this arises, it is necessary review the basics of reactive power and voltage stability.

The well-known reactive power concept of the PQS power triangle was proposed in 1910 [1]. It is defined, even now, only for sinusoidal signals in 1-phase and balanced 3-phase systems, such as in the International Electrotechnical Vocabulary [2]. Reactive power for distorted signals is not defined. The effects of half-wave transformer saturation caused by GICs are outside the definitions of reactive power. Despite this, the effects of GICs on power systems are typically modelled by an increase in transformer Q (or Q-loss), such as in papers 10415 and 10944.

What is this reactive power, and how is it measured? Q is the orthogonal (right angle) component of power P, except that Q is not a power in the physical sense and was given a different unit: var. Many researchers, notably Tenti and Czarnecki (and their co-authors), have proposed alternatives with further orthogonal components associated with unbalance, scatter, or harmonics. The IEEE Standard 1459-2010 defined a relationship $S^2=P^2+Q^2+D^2$ and for this note we can call D the residual non-active power. However, the measurement is still not defined, but left to the meter manufacturers to choose their own approach. As a result, NEMA reported in 2011 that the results of different reactive power meters differed widely [3]. Clearly, the equation $Q_{LOSS}= V_{pu}.k.I_{GIC}$ (and how the constant k was measured) needs further consideration.

An alternative General Power Theory for systems with any number of wires, unbalance, v-i displacement, and distortion was published in 2020 [4]. Among other parameters, it defines a relative efficiency of delivery and how it is affected by harmonics and/or unbalance. A Session paper in 2020 introduced its application to GICs. Two recent papers describe applications to systems with non-linear unbalanced loads [5] and the compensation of the effects of GICs [6], and another, more extensive, paper is in review.

The Q-loss used in many papers to assess voltage stability in the presence of GICs must be viewed as an approximation of the physical performance of a system – with unknown uncertainty. Similarly, Q during a transient also violates its standard definition.

Converter technologies are not constrained to the 120° phase angles of rotating machines, nor to balanced outputs and sinusoidal signals and an orthogonal reference frame. Power electronics and novel analytics offer new solutions to power system problems.

[1] A. E, Kennelly, "Vector power in alternating-current circuits", *Proc. AIEE*, vol. 29, issue 7, p1023-1057, 1910. doi: 10.1109/PAIEE.1910.6659879.
[2] Electropedia, IEC Electrotechnical Vocabulary, online at http://dom2.iec.ch/iev.

[3] NEMA C12.24 TR-2011 “Definitions for calculations of VA, VAh, VAR, and VARh for poly-phase electricity meters” 2011, National Electrical Manufacturers Association, Rosslyn, USA.
[4] M. Malengret and C. T. Gaunt, “Active currents, power factor, and apparent power for practical power delivery systems”, *IEEE Access*, 2020 doi: 10.1109/ACCESS.2020.3010638.
[5] C. T. Gaunt, P. J. Cilliers, M. J. Heyns, S. I. Lotz, H. K. Chisepo, *et al*., “Calculations leading to voltage stability and transformer assessment in the presence of geomagnetically induced currents,” *Cigre Session*, Paper C4-113, 2020.
[6] H. K. Chisepo, C.T. Gaunt, and P. Jankee, “Applying and comparing the general power theory compensation for unbalance and harmonics,” *Universities Power Engineering Conf. (UPEC)*, paper 147, Istanbul, Aug-Sep. 2022.
[7] H. K. Chisepo and C. T. Gaunt, “Towards asymmetrical modeling of voltage stability in the presence of GICs,” *IEEE PowerAfrica*, Paper 193, Kigali, Aug. 2022.