



Fundamentals of Measurement Transducers and Synchronizers

Course Number: EE-04-930

PDH: 4

Approved for: AK, AL, AR, DC, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868

Indiana Continuing Education Provider #CE21800088

Maryland Approved Provider of Continuing Professional Competency

New Jersey Professional Competency Approval #24GP00025600

North Carolina Approved Sponsor #S-0695

NYSED Sponsor #274

Course Author: Velmir Lackovic

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.

After the course has been purchased, review the technical material and then complete the quiz at your convenience.

A Certificate of Completion is available once you pass the exam (70% or greater).

If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).

If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.



FUNDAMENTALS OF MEASUREMENT TRANSDUCERS AND SYNCHRONIZERS

The precise measurement of the voltage, current or other power system parameters is a requirement for any automation and control process, ranging from automatic closed-loop control to the information sampling for statistical needs. Measurement of these quantities can be achieved in a different ways, including the application of direct-reading devices as well as electrical measuring transducers. There is a wide range of measurement instruments that are used to gather information and convert it into information that can be used by the operator. Typically, the instruments are classified depending on possibility for local or remote application.

TYPICAL TRANSDUCER FEATURES

Transducers generate precise DC analogue output, typically a current, which corresponds to the measures value. They also give electrical isolation by instrument transformers, which is frequently referred to as 'Galvanic Isolation' and they are located between the input and the output. This is safety characteristic, however cables from the output points to any receiving devices can be minimized and have a lower insulation specification. The benefits over discrete measuring devices are as follows:

- placed close to the measurement source, decreasing instrument transformer burdens and improving safety by avoiding long wiring runs
- possibility to install display devices remotely from the transducer
- possibility to use several displays per transducer
- the burden on CTs/VTs is significantly lower

Transducers outputs may be utilized in many forms – from simple presentation of measured quantities for an operator, to being used by a power network automation center to select the control strategy. Transducers may have one or more inputs and/or outputs. The inputs, outputs and any auxiliary connections are isolated from each other. There may be more than one input value and the measured quantity may be a function of one or more of them. Regardless of the used measurement transducer, there will typically be a selection between discrete and modular types. The modular type is typically plug-in unit to a standard rack. The position and user-requirements will dictate the transducer type selection.

TRANSDUCER INPUTS

Transducer input is typically taken from transformers. These inputs can come in many different formats. Ideally, to achieve the best precision, metering-class instrument transformers need to be utilized since the transformer errors will be added, albeit algebraically, to the transducer errors. Nevertheless, it is frequent to use transducers to protection-class instrument transformers and from that reason transducers are typically selected so that they can withstand significant short-term overloads on their current inputs. Typically, transducer appropriate for connection to protection-class instrument transformers should withstand:

- 300% of full-load current continuously
- 2500% of full-load for three seconds
- 5000% of full-load for one second

The input impedance of current input circuit should be minimal. The input impedance of voltage input circuit should be maximized. This eliminates errors due to impedance mismatch.

TRANSDUCER OUTPUTS

Transducer output is typically a current source. This implies that, within the transducer output voltage range, display elements can be installed without limit and without any need for transducer adjustment. Compliance voltage sets the output circuit maximum loop impedance, so a compliance voltage high value allows remote installation of an indicating instrument. In situations, when the output loop is utilized for control purposes, suitably sized Zener diodes are typically fitted across the terminals of each of the elements in the series loop to protect against the possibility of their internal circuitry becoming open circuit. This assures that a faulty instrument in the loop does not cause overall failure of the output loop. The transducer output constant current nature simply increases the voltage and continues to drive the precise output signal round the loop.

TRANSDUCER PRECISION

Typically, accuracy is of great importance. However it has to be noted that accuracy can be specified in few ways and may only apply under specified application conditions. Terminology presented in IEC 60688 clarifies typical terms and relates them to practical application. The transducer accuracy will be impacted, to a higher or lesser extent, by many components, known as influence factors. User has little or no control over them. Complete list of influence factors is provided in Table 1. The accuracy is verified under an agreed set of circumstances known as reference conditions. The reference conditions for each of the influence factors can be cited as a single value (e.g. 25°C) or a range (e.g. 10-50°C).

Table 1. Transducer influence factors

Input current and voltage	Common mode interference
Input quantity distortion	Input quantity frequency
Power factor	Unbalanced currents
Interaction between measuring elements	Ambient temperature, self-heating and external heat
Auxiliary supply voltage	Auxiliary supply frequency
External magnetic fields and series mode interference	

Error calculated under reference circumstances is known as the intrinsic error. All transducers that have exactly the same intrinsic error are organized in special accuracy group which is labeled with the class index. The class index is exactly the same as the intrinsic error presented as a percentage (e.g. a transducer with an intrinsic precision of 0.2% of total scale has a class index of 0.2). The class index classification utilized in IEC 60688 demands that the change for each of the influence parameters be precisely related to the intrinsic error. This means that the greater the accuracy presented by the producer, the changes must be lower. Because there are numerous influence factors, the changes are separately analyzed, whilst keeping all the other influence factors at reference conditions. The nominal range of transducer usage is the typical transducer operating range as defined by the producer. The nominal application range will be wider than the reference value or range. Within the nominal transducer application range, additional errors add up. That results in an extra error. This extra error is limited for any particular influence factor to, at most, the value of the class index. Table 2 presents performance characteristics of a common transducer range (accuracy class 0.5).

Table 2. Common transducer characteristics

Influence Factor	Reference Range	Max. Error-Reference Range %	Nominal Operating Range	Max. Error-Nominal Range
Input frequency	45...65Hz	0.5%		
Power factor	$\cos \varphi = 0.5 \dots 1$	0.25%	$\cos \varphi = 0 \dots 1$	0.5%
Unbalanced current	0...100%	0.5%	-	-
Aux. supply DC voltage	24...250V DC	0.25%	19V-300V	0.25%
Input Voltage, V_n	$V_n=50...500V$ 80...120%	0.25%	0-120%	0.5%
Self-Heating	1...30 min	0.5%	-	-
Output load	10...100%	0.25%	-	-
Waveform crest factor	1.41 (sine wave)	-	1.2...1.8	0.5%

Influence Factor	Reference Range	Max. Error- Reference Range %	Nominal Operating Range	Max. Error- Nominal Range
Ambient temperature	0°-50° C	0.5%	-10°-60°C	1.0%
Continuous operation	Continuous >6h	0.5%	-	-
Output common mode interference	100V 50Hz RMS output to earth	0.5%	-	-
AC Aux. Supply frequency, f_n	90...110% f_n	0.25%	-	-
External magnetic fields	0...0.4 kA/m	0.5%	-	-
Output series mode interference	1V 50Hz RMS in series with output	0.5%	-	-
Input current, I_n	$I_n=1A, 5A$ 20...120%	0.5%	0-120%	0.5%

Misunderstandings happen in defining the operation under real service conditions. The output signal is typically a D.C. analogue of the measurand, but is found from alternating input factors and will usually contain alternating part, or ripple. Ripple is specified as the peak-to-peak measure of the alternating portion of the output signal even though some producers quote 'mean-to-peak' or 'r.m.s.' values. The conditions under which the quantity of the ripple has been measured must be presented, e.g. 0.35% r.m.s. = 1.0% peak-to-peak ripple. Under varying conditions of the measurand, the output signal does not instantly follow the variations but is time delayed. This happens due to the filtering needed to decrease ripple or, in numerical transducers, stop aliasing. The degree of delay is known as the response time. To a certain limit, ripple and response time are related. The response time can typically be decreased at the expense of increased ripple, and vice-versa. Transducers with shorter response times than normal can be provided for those situations where the power system goes through dips, swings, and low frequency oscillations that have to be supervised. Transducers with current output have a maximum output voltage that is known as the compliance voltage. If the load resistance is great and therefore the compliance voltage is surpassed, the transducer output is no longer precise. Few transducers are qualified by the manufacturer for use on power systems where the waveform is not a pure sinusoid. They are known as 'true r.m.s. sensing' transducer types. For these types, the waveform distortion factor is an influence factor. Other transducers are known as 'mean-sensing' and are made to react to the r.m.s. quantity of a pure sine wave. If the input waveform gets distorted, errors will happen. For instance, the error due to third harmonic distortion can equal to 1% for every 3% of harmonic. Once set up, the user anticipates the transducer accuracy to stay constant over time.

The application of high quality elements and conservative power ratings will help to provide long-term stability, but different circumstance at site can cause performance variations that may need to be compensated for during the equipment lifetime.

DIGITAL TRANSDUCER PRINCIPLES

Digital power system transducers use the same technology as digital and numerical protection relays. The analogue signals obtained from VTs and CTs are filtered to prevent aliasing, converted to digital form using A/D conversion, and then signal processing is used to extract needed data. Sample rates of 64 samples/cycle or higher can be applied, and the accuracy class is typically 0.2 or 0.5. Outputs can be both digital and analogue. The analogue outputs will be impacted by the factors affecting accuracy. These factors are described above. Digital outputs are commonly in the form of a communications link, with RS232 or RS485 serial. Also RJ45 Ethernet connections are typically available. The response time may decrease in comparison to analogue transducers, depending on the rate at which information is transferred to the communications link and the delay in processing information at the receiving end. As a matter of fact, all of the influence factors that impact a common analogue transducer are also present in a digital transducer in some form. However, the final errors may be lesser than in an analogue transducer and it may be more stable over a long period of time. The benefits of a transducer with numerical technology are:

- enhanced long-term stability
- more precise r.m.s measurements
- enhanced communications facilities
- programmability of scaling
- wider range of features
- minimal size

The enhanced long term stability cuts down costs by extending re-calibration intervals. More precise r.m.s measurements give the user improved accuracy data, particularly on supplies with substantial harmonic content. The enhanced communications facilities allow many transducers to use the same communications link, and each transducer to give few measurements. This decreases necessary interconnecting wiring and number of transducers. Remote or local programmable scaling of the transducer allows scaling of the transducer at the site. The scaling can be modified to reflect modifications in the power system, or to be re-applied elsewhere. Modifications can be obtained via the communications link, therefore eliminating the requirement for a site visit. It also eliminates the risk of the user defining an incorrect scaling factor and having to return the transducer to the producer for modification.



Purchase this course to
see the remainder of
the technical materials.