Technical Information

TI/FEX001-EN

Electromagnetic Flowmeters with AC Magnetic Field Excitation for Demanding Applications

Instrumentation Solutions

ABB Instrumentation

1 Indroduction

If the volumetric flow of conductive fluids is to be metered, Electromagnetic Flowmeters (EMF) have been the first choice. For approx. 80 % of all applications pulsed DC field excitation (this is the type of excitation for the magnetic field coils) technology can be used without concerns, e.g. for the continuous flow metering of water. There are however applications, which due to their physical or hydraulic characteristics, require the use of an EMF with AC magnetic field excitation. Included in these application, among others, are fluids with a high solids content (see Fig. 1-1:) or with very low conductivity.

Fig. 1-1: AC Magnetic Field EMF in a Deinking Process (DIP)

Electromagnetic Flowmeters have been proven and tested over decades in nearly all sectors of industry. Their popularity is primarily due to their smooth, unobstructed meter pipe which adds no additional pressure drop and which can be easily cleaned. The requirements on the measurement technology are lower or higher dependent on the sector. In a paper mill, e.g. in the stock flow an undamped and noise free signal is of primary importance, so that the surface speed control operates correctly and the required paper quality is achieved. In blending application for the production of yogurt with fruit a "spike" free output signal is imperative, otherwise a correct mixing of the fruit and "white mass" is not possible.

Electromagnetic Flowmeters with "pulsed DC excitation" have often been pushed to their limits in these applications. The result is a noisy or spiky output signal, which during the process leads to inaccurate and/or poor reproducibility.

2 Principle of Operation EMF

The measurement principle of the EMF is based on Faraday's Laws of Induction which states: A voltage is induced in a conductor as it moves through a magnetic field. This principle is applied to the conductive fluid as it flows through a magnetic field generated perpendicular to the flow direction by two magnet coils. The voltage induced in the fluid is measured at two electrodes located diametrically opposite to each other. This measurement signal voltage is proportional to the magnetic induction, the electrode spacing and the velocity of the fluid. Noting that the magnetic induction and the electrode spacing are constant, leads to a proportionality between the flow velocity and the signal voltage. Since the volume flowrate can be calculated from the average flow velocity and flow area it follows that the volume flowrate is linearly proportional to the signal voltage. The induced signal voltage is converted to scaled, analog and digital signals in the converter.

There are two types of excitation for the magnet coils, pulsed DC and AC. In EMFs with pulsed DC magnetic field excitation the current to the magnet coils reverses its polarity at predefined time intervals (see Fig. 2-1:). Due to the varying current during the rise time for each cycle, the measurement window is limited to 25 % of the excitation time, i.e. the flow signal is only integrated during this time interval. EMFs with pulsed DC excitation usually operate at frequencies between 6 ¼ and 25 Hz.

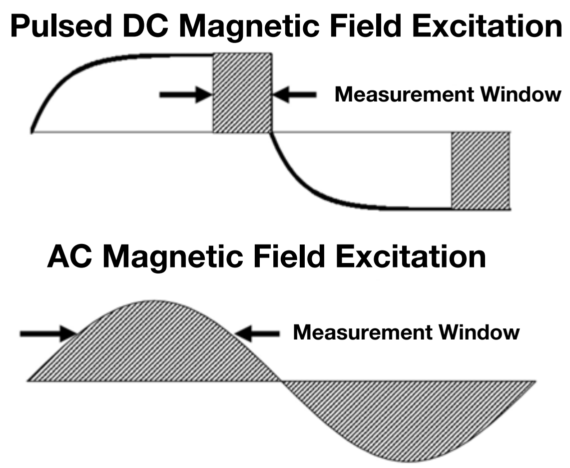

Fig. 2-1: Comparison Pulsed DC Excitation / AC Magnetic Field Excitation

3 More Demanding Applications

The limited applicability of EMFs with pulse DC field excitation, alluded to above, e.g. multiphase fluids, can be seen in Fig. 4-1:. In the figure the noise spectrum of such a fluid at the electrodes is shown. In the operating range of the pulsed DC field meters (to 25 Hz) the noise content is the greatest. In addition, higher odd harmonics (3, 5, 7…) caused by the field excitation frequency, which exist in the pulse DC instrument, must also be processed. These also cause an increase in the noise and therefore unsteadiness in the output signals from the EMF.

4 Rescue Using AC Field Technology?

The magnet coils in an EMF with AC field excitation are supplied from an AC current supply. Since the excitation frequency is considerably higher that the frequency of the pulsed DC excitation, the above mentioned limitations of the pulsed DC excitation not longer apply. The measurement window (see Fig. 2-1:) is almost 100 %, i.e. the flowrate integration begins when the excitation crosses zero, that is continuously. In addition to these advantages however, this is accompanied by increased sensitivity to line frequency noise signals (see Fig. 4-1:) since the magnet coils are usually operated at the line frequency. An additional disadvantage is a definite decrease in the accuracy (1 % of max.) compared to the pulsed DC system.

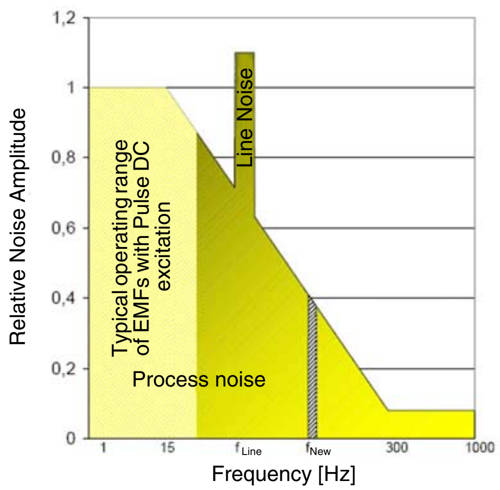

Fig. 4-1: Noise Spectrum for a Multiphase Fluid

5 AC Field Excitation Rejuvenated

A recent new development in AC field excitation has enhanced the performance. The emphasis of this development was to eliminate the disadvantages of the AC field excitation system. This was partially accomplished by increasing the excitation frequency to 70 Hz (see Fig. 4-1: ➜ f_{New}). A further improvement was the introduction of modern digital signal processing (DSP) techniques together with narrow band width filters. In order to realize a noticeable improvement in the accuracy, not only did the converter need to be redesigned, but the flowmeter primary also had to be optimized. It was possible to compensate for fluid temperature independent eddy current effects by utilizing a 3rd coil to measure the field strength. At the same time all adjustment and noise reduction components in the connection box of the flowmeter primary were eliminated.

The AC field EMF FSM4000 (Fig. 5-1:) is the result of this optimization. In addition to the improved suppression of noise signals, the accuracy was improved by a factor of 2 to 0.5% of rate and the zero stability dramatically improved.

Use of a magnet coil supply current independent of the line frequency allowed for the first time an AC field instrument to utilize a supply voltage of 24 V DC. During the incorporation of these innovations, backward compatibility was a major consideration, so that flowmeter primaries as old as 20 years could be operated with the new converters. These instruments are available in a size range from DN 1 to DN 1000 [1/25" to 40"]. The flowmeter liner options are PFA/PTFE/Hard or Soft Rubber or a special "Ceramic- Carbide" (for highly abrasive fluids). For the flowmeter primaries in the stainless steel design various process connections have been granted a 3A Certificate and EHEDG approval. In addition the benchmark specifications now include a minimum conductivity of the fluid 20 µS/cm or 0.5 µS/cm.

Fig. 5-1: AC field Excitation EMF System FSM4000

6 Expanded Application Spectrum

As a result of the almost continuous integration of the flow signal, pulsating flows (produced by piston, diaphragm and hose pumps) up to a stroke frequency of 400 strokes/min can be metered practically errorless. Pulsed DC field instruments must be operated at higher frequencies (typ. 25 Hz) for these applications, and even then, the measurement limit for pulsating flows lies at approx. 140 strokes/min.

Experiments with 3.6 % paper pulp and 5 % air content resulted in an error less of than 1 %. Pulsed DC field instruments in this application (due to their inability to integrate the entire signal) exhibited errors with two digits. Liquids with extremely low conductivities (e.g. liquid sugar) and/or extreme internal noise (e.g. distilled water) are metered accurately above 0.5 µS/cm. Fluid with solids content up to 15 % otro in a pulp slurry or 22 % total solids [TS] in sludge can be confidently measured.

7 Summary

In spite of optimized pulsed DC field systems the AC field EMFs today have an important place in solving difficult application problems.

Systems with pulsed DC field technology (due to their inability to integrate the entire signal and poorer signal/ noise ratio) cannot satisfy the requirements of the entire application spectrum, especially in case of bigger diameters (> DN 200) the excitation frequency is limited by the magnetic system (refer to Fig. 4-1:).

As a result of innovations in the AC field technology the limitations (unstable zero, poorer accuracy than pulsed DC field instruments, no 24 V DC supply) are things of the past. The FSM4000 defines the new market standard in AC field technology.

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ABB Limited
Oldends Lane, Stonehouse
Gloucestershire, GL10 3TA
UK
Tel: +44 (0)1453 826661
Fax: +44 (0)1453 829671

ABB Inc.
125 E. County Line Road
Warminster, PA 18974
USA
Tel: +1 215-674-6000
Fax: +1 215-674-7183

ABB Automation Products GmbH
Dransfelder Str. 2
37079 Goettingen
Germany
Tel: +49 551 905-534
Fax: +49 551 905-555
CCC-support.deapr@de.abb.com