INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT www.ijprvd.info

INNOPOWER™

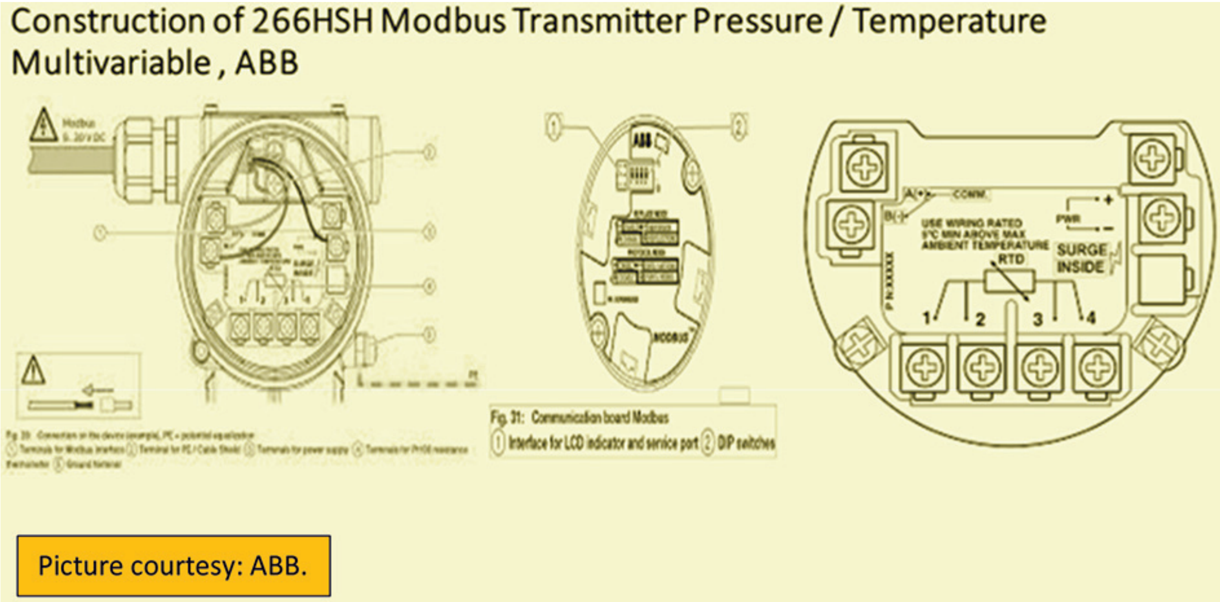
Jayanta Bhattacharya
Chief Editor

Where stands the development and innovation of smart pressure sensor technology

A pressure sensor is a transducer that converts an external pressure stimulus into an electrical or other identifiable output signal according to certain rules. Over the last several decades, the role of pressure sensing in daily life has escalated, leading to the rapid growth of its market size. According to a recent study, the global market for pressure sensors is expected to increase to $15.97 billion by the year 2028 from $8.8 billion in 2018. The basic principle of a piezoresistive pressure sensor is conversion of the pressure stimulus exerted on the device into a resistance variation that can be recorded. A piezoresistive pressure sensor typically consists of a sandwich structure with a piezoresistive material layer intercalated between a pair of parallel electrodes. The piezoresistive layer should offer outstanding electrical and mechanical properties and can be designed as beam, cantilever, or diaphragm for specific needs. They are mostly of 4 types:

1. Piezoresistivity : The basic principle of a piezoresistive pressure sensor is conversion of the pressure stimulus exerted on the device into a resistance variation that can be recorded. A piezoresistive pressure sensor typically consists of a sandwich structure with a piezoresistive material layer intercalated between a pair of parallel electrodes.
2. Capacitance: A typical capacitive pressure sensor converts applied pressure into a capacitance variation by using a parallel electrode capacitor. In a typical configuration, one electrode of the capacitor is deflected under pressure stimuli while the other electrode is fixed. The device capacitance follows the equation $C = \varepsilon_0 \varepsilon_r A/d$, where ε_0 and ε_r respectively represent the permittivities of the vacuum and dielectric material between the capacitor electrodes and A and d respectively represent the overlap area and distance between two electrodes. Deflection of the electrode leads to a change in d (compression force) or A (shear force), resulting in variations in capacitance that can be measured by a capacitance bridge circuit.
3. Piezoelectricity: The piezoelectric effect was first described by the Curie brothers in 1880. When a piezoelectric material is under external stress, its two surfaces become positively and negatively charged. This phenomenon has been used to develop piezoelectric pressure sensors in which pressure stimuli are directly converted into electrical potential variations. PZT thin films are conventionally used as active materials, usually sandwiched between two electrodes, in micro piezoelectric pressure sensors.
4. Resonance: The current resonant devices are widely used in the sensing field on account of their improved sensitivity and reliability. When these devices are used as pressure sensors, pressure-induced stresses change their natural frequencies. Compared with conventional pressure sensors, resonant pressure sensors have been demonstrated to enable higher sensitivity and precision because their frequency signals are more immune to environmental noises.

Multivariable pressure sensors measure volumetric pressure as a function of both absolute and differential pressure and compensate that value with temperature measurements to provide accurate mass flow readings of a system. This is crucial for applications where gases, vapors, or fluids in a flow system are subject to density changes. Such applications would typically rely on separate measurement components to acquire the differential pressure, the static pressure, and the temperature values of a pressure-sensitive component, with an external calculator providing the system's mass flow calculations. Multivariable pressure sensors provide a novel solution to this tedious method for correcting density changes in temperature-critical pressure components such as pulp and paper boiler housings, and flue gas pipework. Preventative maintenance of differential pressure sensors is essential but inefficient. To counteract the dual issue of costly mechanical downtime, ABB engineered a technology known as Plugged Impulse Line Detection (PILD). While this does not eliminate the



need for routine cleaning of impulse lines and regular pressure sensor diaphragm maintenance, it does provide a basis for more efficient predictive diagnostics.

PILD technology uses an algorithmic method to predict blockages in impulse lines based on frequency detection. This monitors noise generated by pressure fluctuations within the system and characterizes these frequencies against a reference of normal operation. While the differential pressure sensor is in normal operation, the PILD diagnostic software continuously monitors the noise spectrum of the system to detect deviations from the norm. The sensitivity of this technology is such that it can detect variations in the noise spectrum before pressure measurements are even affected.

Sensor technology has not only become essential to monitor the production processes in manufacturing industry but also is used to ensure the smooth functioning of sub-systems by continuously monitoring vehicle dynamics in automotive industry. As vehicles have evolved to support many more functions, the complexities of the electronic systems inside the vehicles are increasing daily. Today automotive electronics contain various types of sensors (i.e., temperature, pressure, speed, position and air flow) that are utilized in different subsystems to monitor the components from powertrain (engine, transmission and all the onboard diagnostics) to chassis (suspension, braking, lightning, steering and exhaust). There is an enormous demand for robust, highly sensitive, accurate and precise sensors to guarantee the safe operation of vehicles by acquiring real-time diagnosis. The passenger safety and comfort can be improved by early detection of faults and causes. Smart sensors have the ability to prevent failures, reduce the repair time and improve the efficiency of vehicles by detecting faults through analysis of signal characteristics. Pressure is a critical parameter in many engineering fields and it also of increasing importance in automotive industry. Pressure sensors are used in many parts of vehicles (e.g. manifold air pressure, oil pressure, in-cylinder pressure, fuel vapor pressure, transmission fluid pressure, exhaustive gas filters pressure, tire pressure and side airbags pressure etc.).

In a typical vehicle, the reliability of pressure sensors enhances the engine performance and ensures its' compliance with environmental standards. Recently, the pressure sensors evolved and became more sophisticated to meet the more demanding measurement requirements of automotive applications.