Evaluation of Energy Harvesting for IoT Sensor Nodes in Surgical Instrument Lifecycle – Industrial Perspective

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Digitalization is an ongoing trend among the medical industry and healthcare facilities. More and more medical instruments and devices are equipped in several sensors and connectivity modules, as this opens new business opportunities for industry as well it increase automation of documentation routines increasing safety. However, each electronic sensor needs a power source. The problem arises with the usual lifecycle of the surgical instrument in the healthcare facility. Washing, disinfection and sterilization processes involve high temperatures, moisture and water. Especially steam sterilization, which is the cheapest and the most popular method, is dangerous for electronics. It involves high temperature, up to 140°C, and pressure changes from 0 to 3 bar. These factors are the main cause of difficulty in finding a reliable power source for such devices. Existing primary batteries needs to be replaced after several sterilization cycles which needs additional care. Rechargeable secondary batteries cannot be used due to the high temperature leading to internal heating of the cells and finally to thermal runaway and explosion.

Energy harvesting could solve majority of the problems mentioned above. Thermoelectric generators (TEG) can produce the electric power from a temperature gradient across its sides. It is a stable and clean energy source for the sensor systems especially for heavy industry as well as space applications. However, this technology is still not present in medical industry. It is caused due to the temperature distribution in the autoclave and problems in inducing appropriate thermal gradient for the TEG.

In this paper authors present a power supply system for sterilizable low power medical devices. The system is based on the TEG connected with heat storage unit (HSU) and with the casing of the module on the other side. The HSU and TEGs itself are insulated from the environment with the layer of aerogel-based foam. Such an arrangement makes the heat transfer possible only across the TEGs plates. The whole system is designed according to the characteristics of the surgical instrument lifecycle. The energy harvested during the washing, drying, and sterilization processes can be used then to power the sensor electronics.

Authors have focused on aspects to provide industrial grade solution, as well as software optimizations to ensure low power consumption of the IoT node. The initial requirements for the energy harvesting system were to generate at least 1.6mW of power over the 80% of the sterilization cycle. The simulations of the heat dissipation through the module are presented and analyzed according to the requirements from the industry. Based on the heat simulations the TEG based energy harvesting system simulation model is being developed. Finally, based on the simulation model optimizations the method of selection the TEG module from the products available from the producers is presented. Finally the simulation results are compared with the results obtained from the tests inside the autoclave. The initial requirements and goals have been met during the tests of the physical prototype.