**Electrical & Electronic Engineering, Software & Electronic Systems Engineering**

**Final Year Projects 2022-2023**

**Real-Time Frequency Measurement**

**Supervisor:** Tim Littler

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|  | Control | X | Embedded Systems |  | High Frequency Electronics |  | Microelectronics |
| X | Electric Power | X | Software |  | Connected Health |  | MEMS |
|  | Cyber-Security |  | Wireless Communications |  | Signal/Image Processing |  | Intelligent Systems |
|  | Digital Design |  | Sensor Networks |  | Data Analytics | X | Electronics |

The operation of AC interconnected power systems is established by rotating generators and is normally maintained within strict limits at a nominal frequency of 50 or 60 Hz (depending on geographic location). If generator output is higher than demand, the rotating machines will tend to increase in speed and the frequency will rise, and vice versa. The mechanical speed of rotation is tightly controlled at the generator to ensure accuracy and stability throughout the power system, irrespective of the electrical load. Thus the frequency is not a constant quantity but varies and is continuously monitored by the generating company against standard time-sources. If long-term tendencies to rise or fall are noticed, the control engineers take appropriate action by regulating the generator outputs. Transmission companies that are fed from the generators independently monitor the power system frequency. The measured frequency is used to assess system stability, power flow, and load variations. The power system frequency is also monitored by distributed frequency protection relays placed at critical load points on the transmission network. The frequency relays are designed to measure the rate of change of frequency (ROCOF) and remove load in the event of frequency transients.

This project will develop a method of real-time power system frequency measurement and implement the method on a COTS (commercial-off-the-shelf) small-footprint platform (e.g. Raspberry Pi/Arduino/Teensy/Pi Zero). Operating scenarios will include: off-nominal frequencies, harmonic distortion, transient distortion, noise components, and incomplete data. The project will require excellent knowledge of C/C++ programming, analogue and digital hardware, basic digital signal processing and power engineering.

**Objectives**

1. Investigate a method of real-time power system frequency measurement for embedded use
2. Develop a real-time algorithm (in C/C++) to measure power system frequency
3. Develop appropriate analogue/digital hardware for COTS interfacing
4. Write C/C++ software to implement the algorithm for real-time measurement on COTS platform
5. Write C/C++ software to implement real-time ROCOF (rate of change of frequency) measurement
6. Evaluate and test frequency measurement with different operating scenarios

**MEng Extension**

1. Develop and implement a front-end digital filtering scheme (e.g. FIR)\*
2. Develop a broad range of realistic test signals with different frequency dynamics\*
3. Implement and evaluate final embedded solution using simulated/measured/laboratory signals\*

This project is best suited to a student with an interest in hardware and software. However, a high proportion of software programming is expected thus the **student should be very confident in the use of C/C++ and be capable of generating executable software** using an appropriate language. **The final implementation must be delivered to the primary supervisor at the end of the project and all unused tools & components returned.**

**Learning Outcomes**

Upon completion of the project you will expect to have:

1. A comprehensive understanding of power system frequency measurement
2. A thorough knowledge of the chosen COTS platform, C/C++ software and implemented approach
3. Developed a grasp of real-time digital signal processing issues and solutions\*

\*MEng