The Application of Coordination to Magnetic Measurement Automation: An SSW System Example

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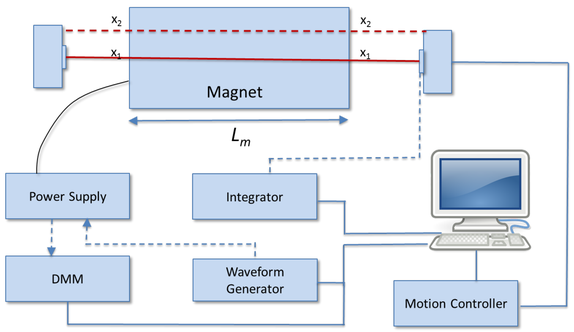
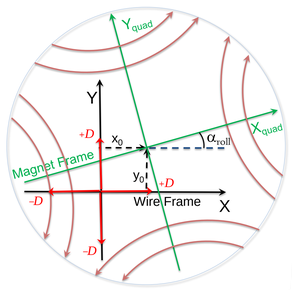
Thu-Mo-Po4.03-04

Single Stretched Wire (SSW)



- Single wire stretched between precision X-Y stages.
- Integrator measures flux change (Φ) caused by wire motion.
- Co- and counter-directional stage motions.
- DC and AC measurements.
- Adjustable wire tensioning for removal of effects from wire sagitta.

SSW Measurements



Quadrupole center:

$$x_0 = -\left(\frac{D}{2}\right)\left(\frac{\Phi_H^+ - \Phi_H^-}{\Phi_H^+ + \Phi_H^-}\right)$$

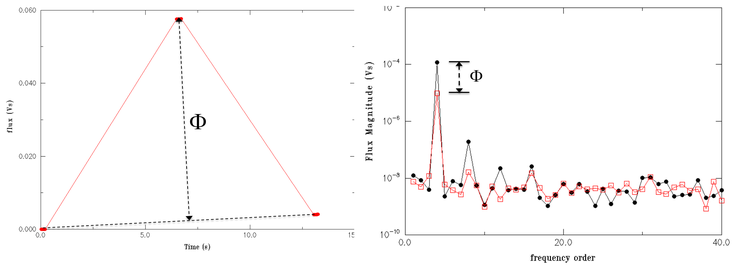
$$y_0 = -\left(\frac{D}{2}\right)\left(\frac{\Phi_V^+ - \Phi_V^-}{\Phi_V^+ + \Phi_V^-}\right)$$

Integrated gradient:

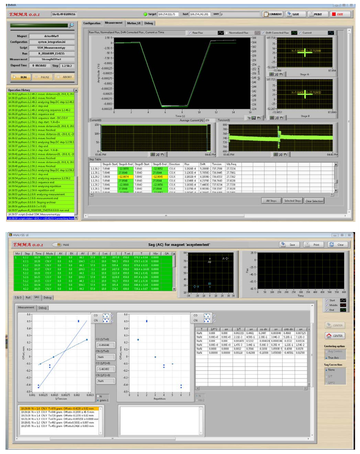
$$\int_0^{L_m} Gdl = \frac{\Phi_H^+ + \Phi_H^-}{cos2(\alpha)D^2} = \frac{\Phi_V^+ + \Phi_V^-}{cos2(\alpha)D^2}$$

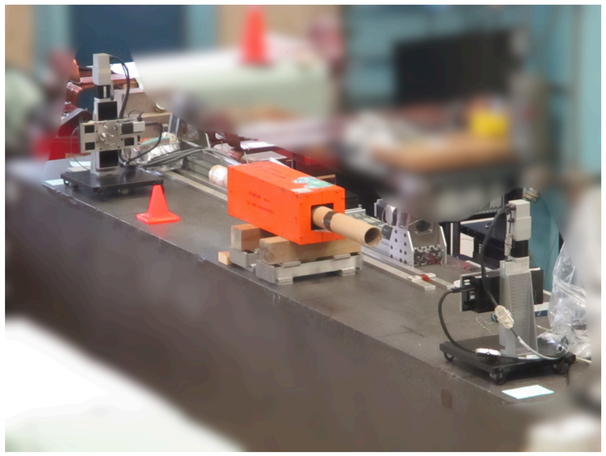
- Quadrupole center measured with co-directional stage motion.
- Roll angle obtained by measuring x_0 as a function of vertical position → the slope yields -2α
- Yaw and Pitch angles obtained by making co- and counter-directional motions with the wire and accounting for geometry between magnet and stages.

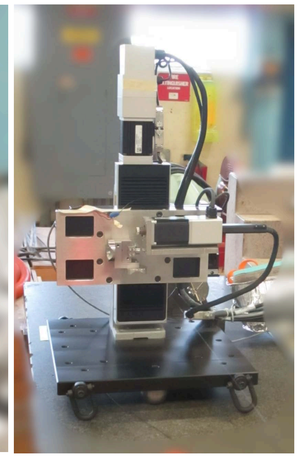
DC and AC Measurements



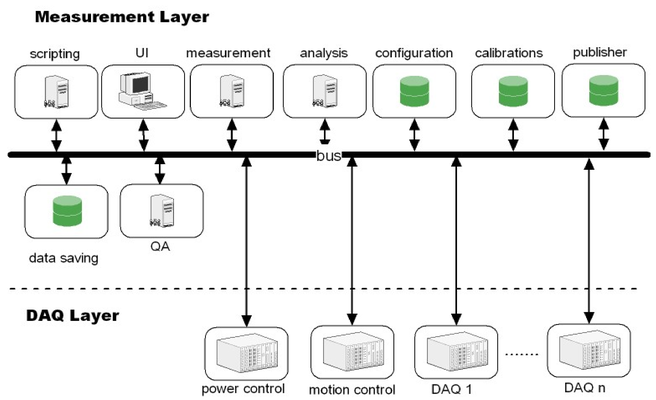
- DC Measurement: Φ measured between 0 and +/-D positions.
- AC Measurement: Φ measured as difference of the Fourier component of flux corresponding to the AC frequency for +D and –D positions.







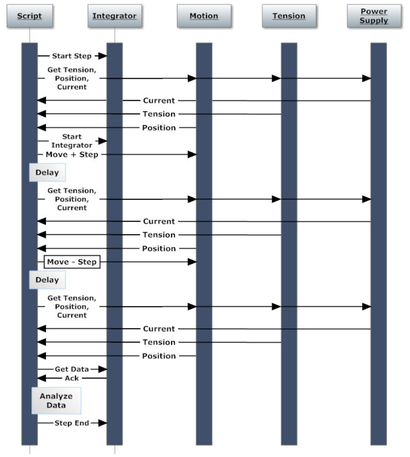
Framework



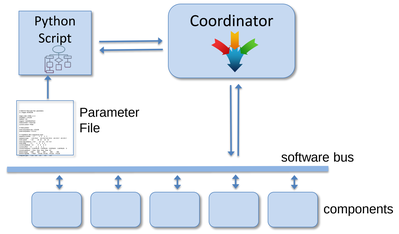
Automation & Coordination

- Automation in measurement systems means completing a measurement task without human intervention, which makes measurement processes more efficient, reproducible and dependable.
- Coordination is a process of ensuring that elements of the system act in a coherent way, leading to correctly performing a measurement.
- Orchestration is a method of centralized coordination, performed by a separate entity (component) devoted to this function.

Coordination Protocol

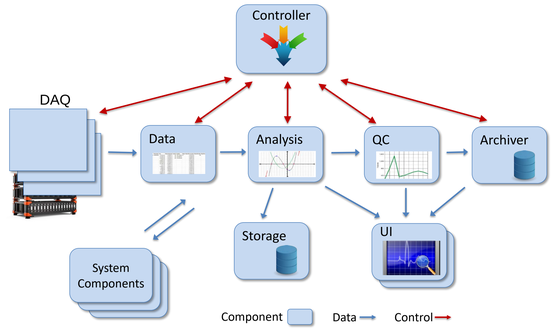


Implementation of Coordination



- The Python script communicates with components via the software bus, directing the flow of execution.
- The script does not process data; it fulfills a purely controlling role
- A script is not intended to contain any measurement parameters; these are read from a separate parameter file.
- The script can also modify component properties.

Separate Control & Data Flows



Conclusion

- The SSW measurement system is automated, thus enhancing measurement repeatability, traceability and dependability.
- Automation is achieved using a set of parameterized Python scripts, which provide coordination of components via orchestration.
- The overall solution is characterized by its high flexibility, reusability and maintainability.
- The system has been used at KEK for measuring magnetic centers and roll angles of the final focus quadrupole system for SuperKEKB.

MT26 International Conference on Magnet Technology
Vancouver, Canada | 2019