METHOD FOR IMPEDANCE MEASUREMENT USING MULTIPLE PHASE SHIFTED CHIRP SIGNALS

IITM Technology Available for Licensing

Problem Statement

- Electrochemical energy systems, like batteries and fuel cells, experience irreversible performance and capacity degradation over time. However, regular **Impedance based diagnosis and management can extend their lifespan**.
- **Conventional** electrochemical Impedance Spectroscopy (EIS) is widely used but **is slow, bulky, and unsuitable for real-time or fast-changing** systems**.**
- Moreover, **current methods need extensive data and struggle with noise/system nonlinearity**, and demand high computational resources.
- There is a need for method of diagnosis that uses phase-shifted chirp signals for **quick, accurate impedance measurement, operable on compact, low-power devices.**

Intellectual Property

- IITM IDF Ref 1741
- **IN 513596 Patent Granted**

TRL (Technology Readiness Level)

TRL 4 Technology Validated in Lab

Technology Category/ Market

Category- Energy, Energy Storage & Renewable Energy

Industry Classification:

Electrochemical Energy Systems; Portable Electronics etc

Applications:

Battery Management System Battery Diagnostics; Fuel Cell Analysis; Embedded systems in portable or compact devices for real-time impedance monitoring and other etc.

Market report:

The global Battery Management System market size was valued at USD 9.1 billion in 2024 and is projected to reach USD 22 billion by 2029 with a CAGR of 19.3%

Research Lab

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1. Provide perturbation voltage or current signal (s) to a system under test
2. Receive transient response to perturbation signal(s)
3. Process the received signal by de-noising and smoothing the signals
4. Compute instantaneous output phase angle of chirp signals
5. Compute instantaneous input amplitude of chirp signals
6. Convert the instantaneous output phase angle to a monotonically increasing function
7. Calculate instantaneous output phase shift of the chirp signals
8. Calculate instantaneous output amplitude of the chirp signal
9. Calculate instantaneous amplitude ratio
10. Calculate impedance of the system

Figure: Illustrates a method of measuring impedance of a system under test.

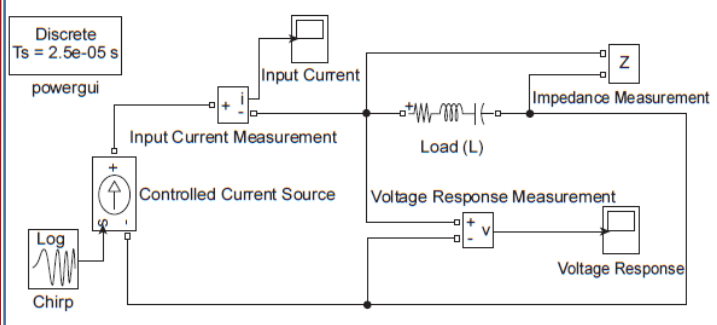

Figure: The master circuit used to generate the test circuits used in the study.

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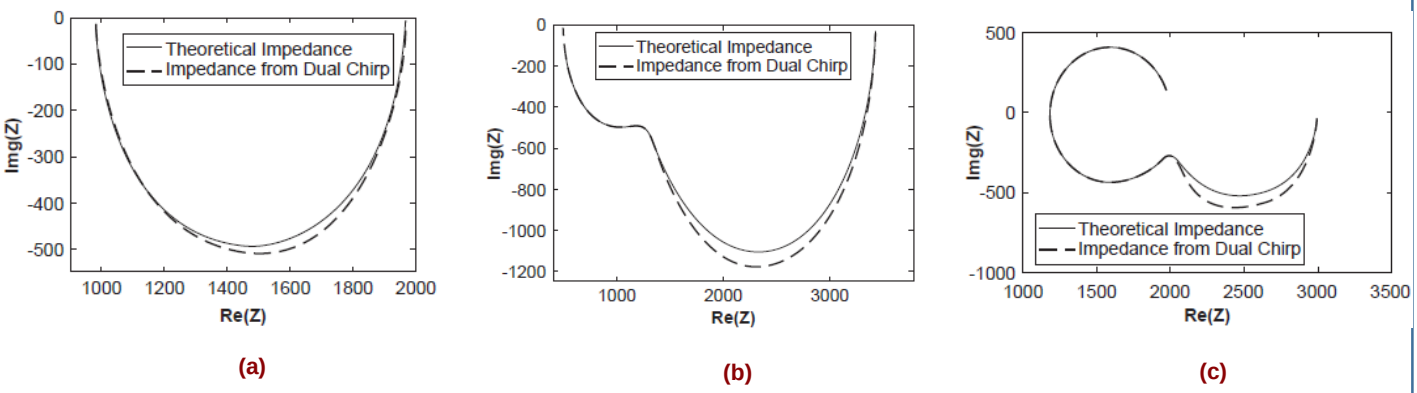

Figure: (a) Simulated impedance profile obtained from dual chirp against theoretical impedance for the test (a) Circuit 1 representing a simple Randles circuit; **(b)** Circuit 2 representing an electrochemical reaction with adsorbed intermediates and (c) Circuit 3 incorporating an RL element

Technology

The invention provides a rapid, precise method for impedance measurement using dual and triple phase-shifted chirp signals, ideal for diagnosing electrochemical systems like batteries, fuel cells, and other dynamic systems..

The method involves perturbing the system with chirp signals (voltage/current), acquiring transient response data, and calculating impedance via instantaneous amplitude ratio and phase shift using computationally efficient algorithms

Operates over a frequency range of 0.001 Hz to 10 kHz, delivering results within 3-7 seconds, with minimal computational power requirements suitable for small, low-power devices.

Offers 10x faster measurement than conventional Electrochemical Impedance Spectroscopy (EIS), ensures high accuracy even for non-linear systems, and minimizes data processing and noise sensitivity.

Enables real-time, portable diagnostics for industries like energy storage, material science, and biotechnology, addressing challenges in conventional impedance measurement systems with scalable and cost-efficient implementation.

Key Features / Value Proposition

- The invention delivers impedance results in 3-7 seconds, significantly faster than the conventional EIS method, which can take over 45 seconds for the same frequency range.
- Measures impedance across a frequency range of 0.001 Hz to 10 kHz with high precision. Existing methods are often slower and lack the ability to analyze dynamic systems with comparable accuracy.
- A comparison of impedance profile estimated using triple chirp analysis method after additional denoising with interval halving in comparison with the theoretical impedance makes a compelling case for its robustness and commercial viability.
- Unlike conventional EIS, which measures at discrete frequencies, the invention uses chirp signals for a continuous sweep, gathering richer data about system properties within a shorter duration.

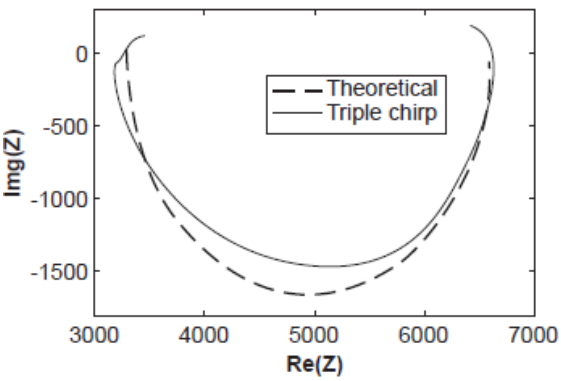

Figure Shows the comparison of impedance profile estimated using triple chirp analysis method after additional denoising with interval halving in comparison with the theoretical impedance.

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