Calculation of Internal Electrical Resistance

and

Power Loss

in a

Electrochemical Cell

by fitting Polarization Curve Data to the

Butler-Volmer Equation

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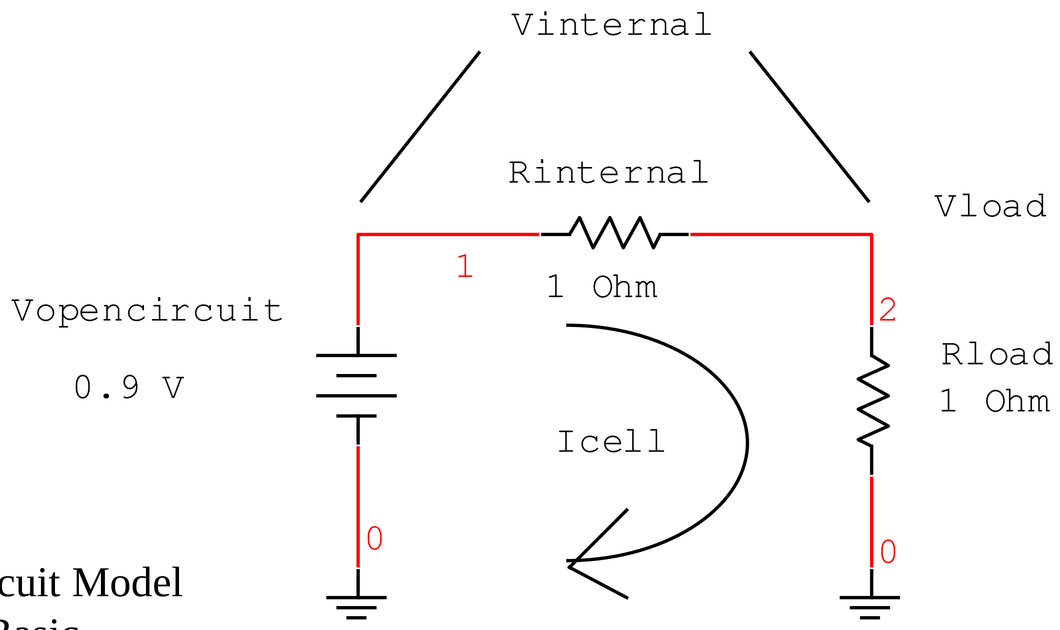
Basic Circuit Model



Simple Circuit Model
For Basic
Power Loss Analysis

Rinternal = Vinternal / Icell   Vinternal = Vopencircuit – Vload

Therefore

Rinternal = (Vopencircuit – Vload) / Icell

Rinternal does not = - d(Vload) / d(Icell)

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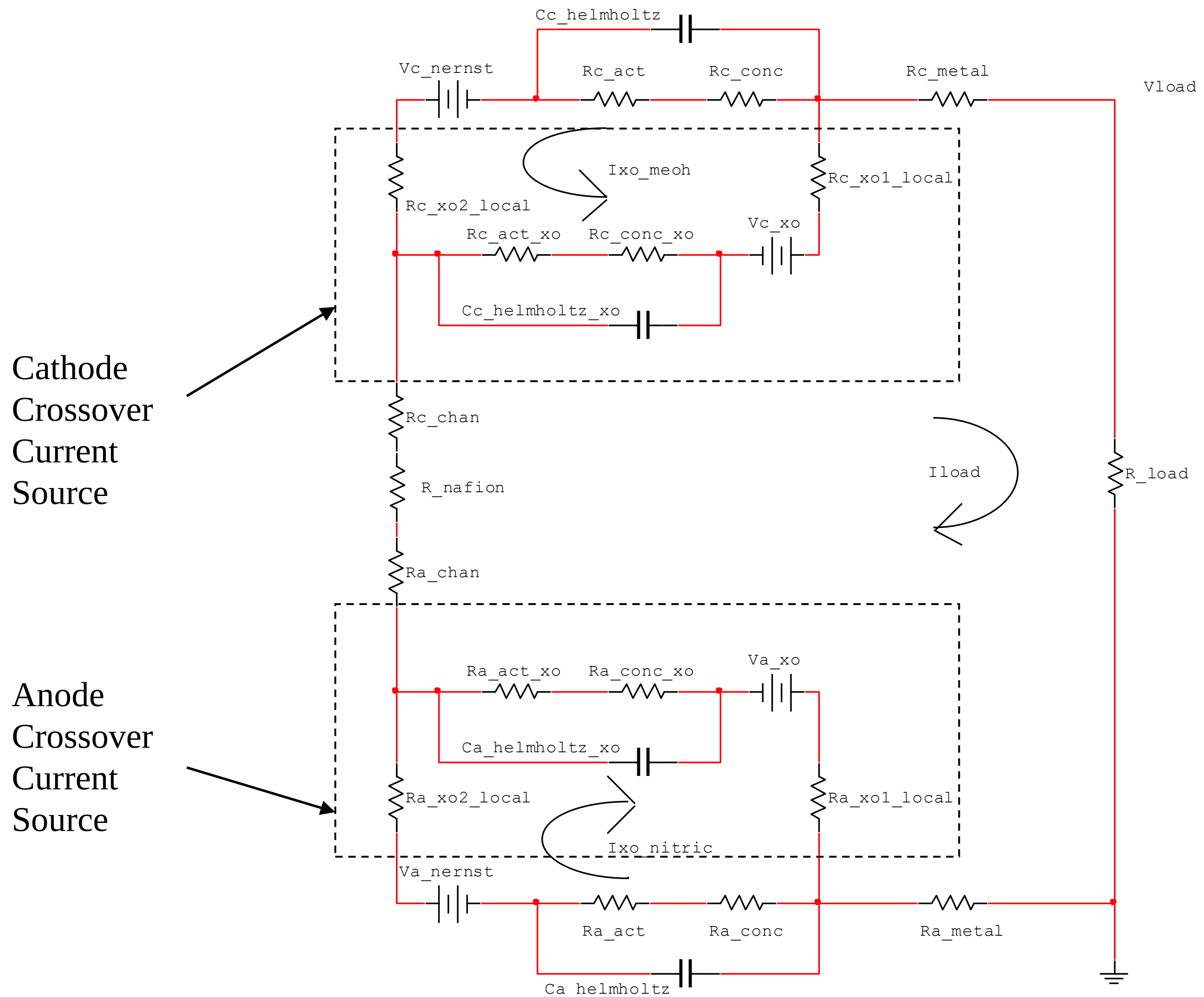

Equivalent Circuit Model For a Cell Showing Anode and Cathode Crossover Loss Mechanisms

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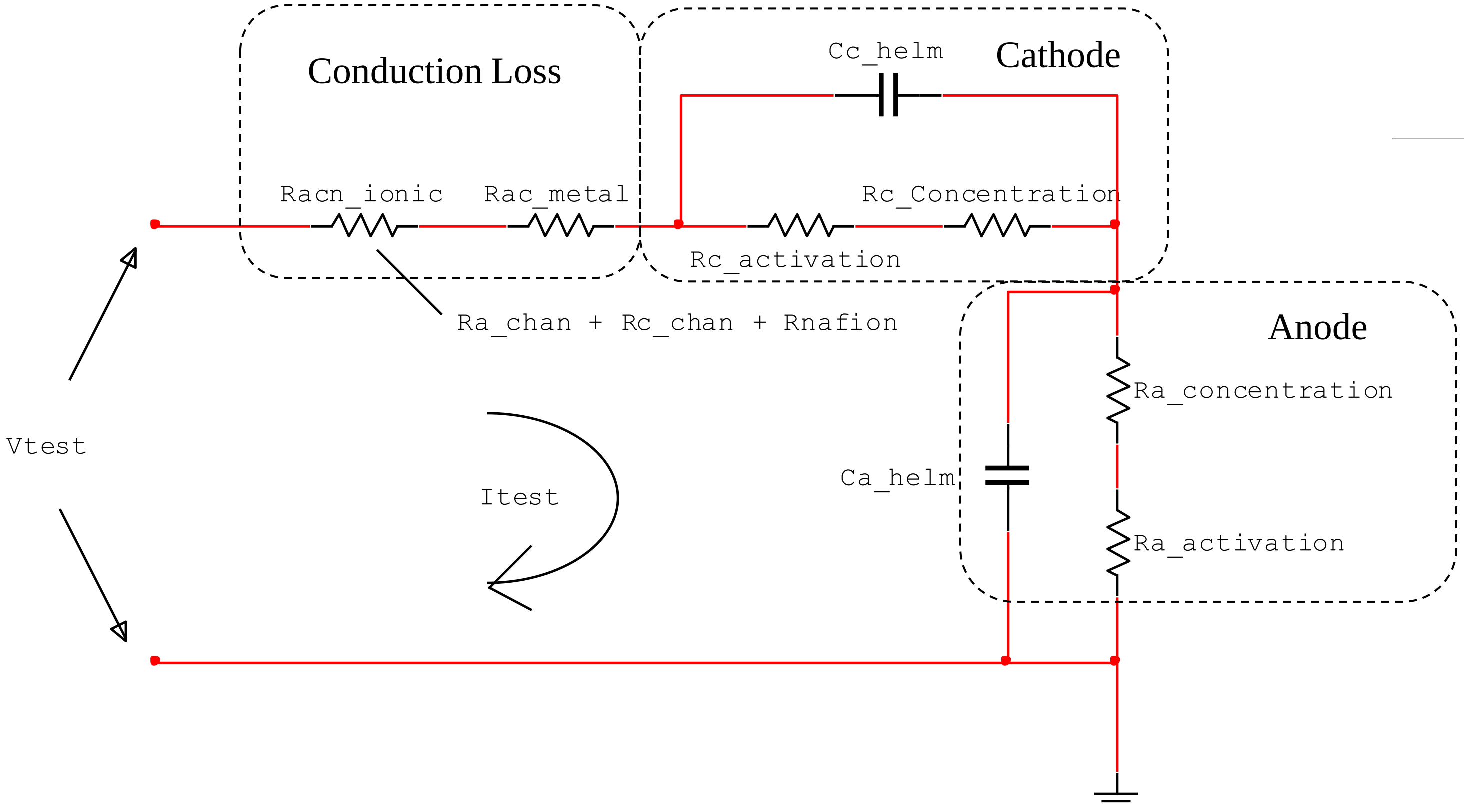

Simplified Equivalent AC Circuit Model for a Two Electrode Cell
for
General Interpretation of Impedance Spectroscopy Data
and
Current – Voltage Transient Performance Analysis

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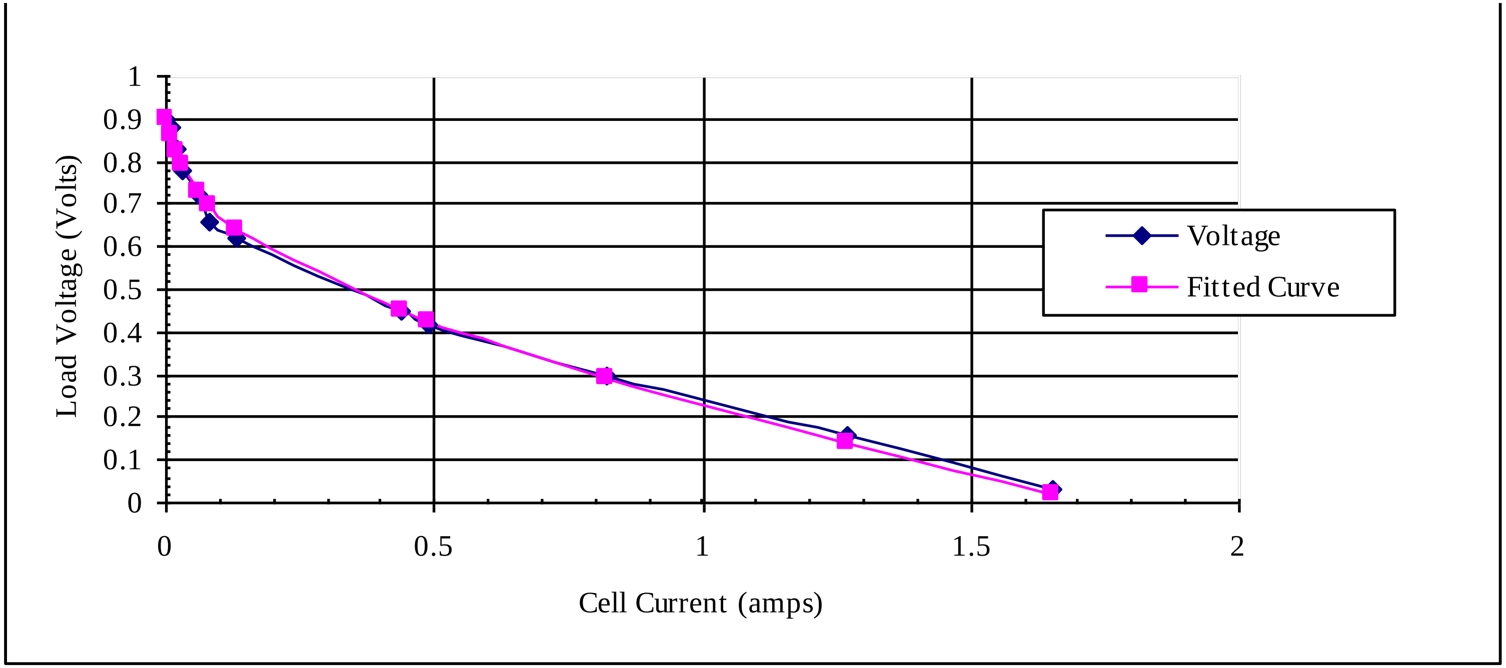
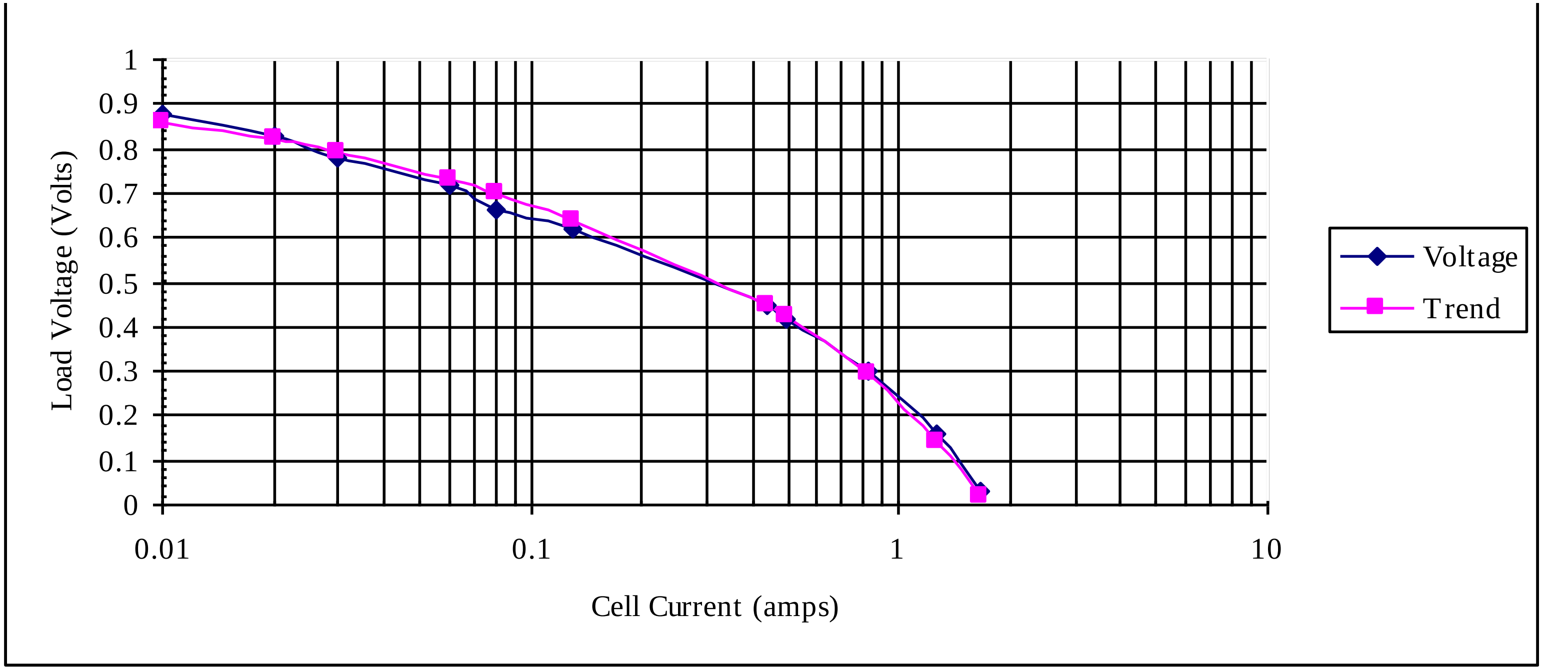
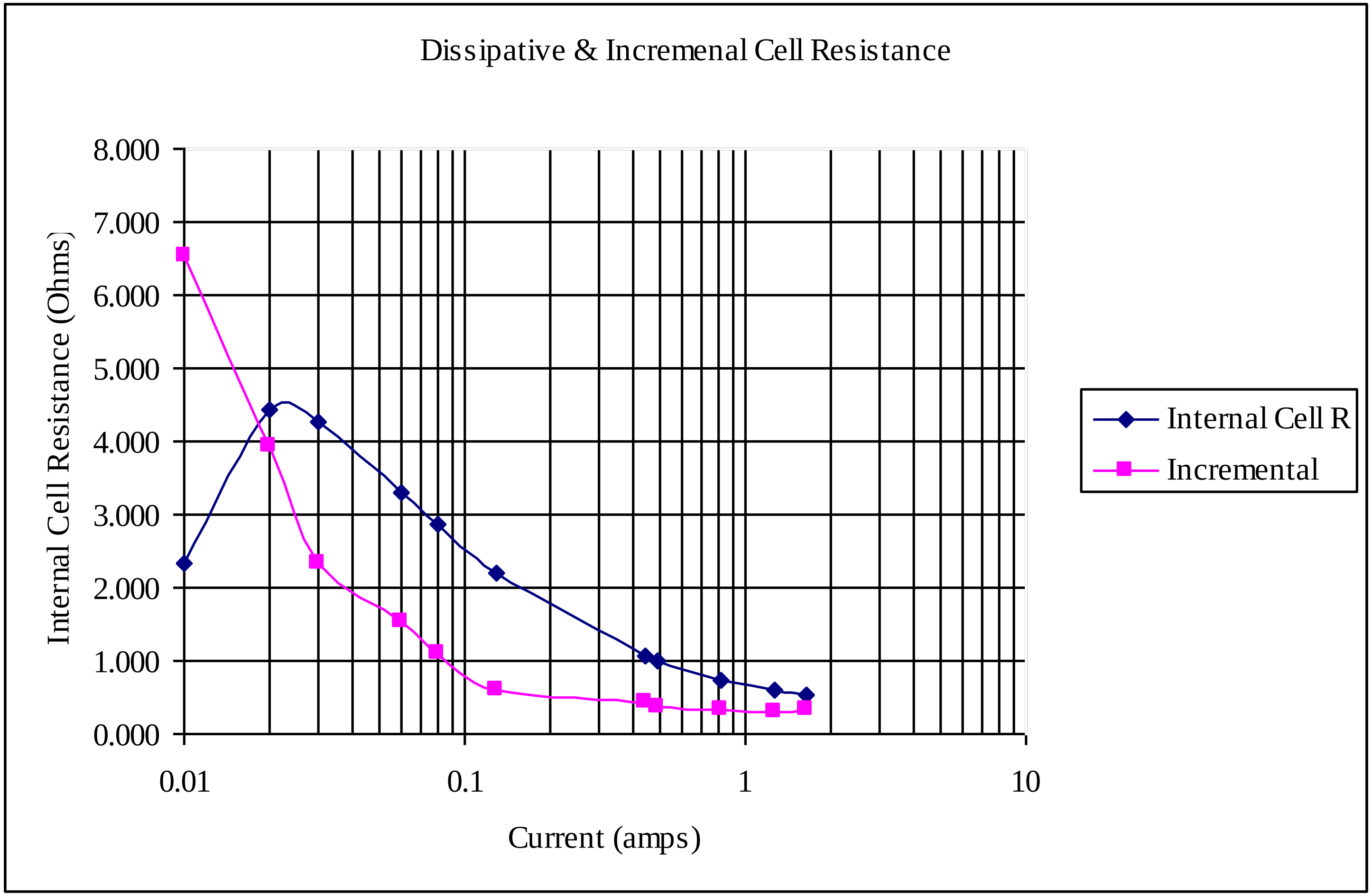


Typical Measured and Fitted Cell Polarization Curve Plots



Log-Lin plot of a typical Measured and Fitted Cell V-I Curve



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Simple Formulaic Model for a Generic Electro-Chemical Cell without Mass Transport Losses

Vload = Vnernst - Vactivation - Vohmic

Vload = Vnernst - Vtaffel * ASINH (Iload / (2 * Io)) - Rohmic * Iload

Vnernst = Thermodynamically reversible electro-chemical potential

Vtaffel = slope of Taffel curve

ASINH = Hyperbolic arc sine function

Iload = Load current

Io = thermodynamic exchange current in the absence of overpotential

Rohmic = electronic resistance in current collectors + ionic resistance in electrolyte and Nafion layer

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Helpful Correlation Formulae Fitted to Measured Data

Vload = .9 - .095 * ASINH (Iload / (2*.012)) - .25 * Iload

Vdrop_internal = .095 * ASINH (Iload / (2*.012)) + .25 * Iload

Rload = [.9 - .095 * ASINH (Iload / (2*.012)) - .25 * Iload] / Iload

Rinternal = [.095 * ASINH (Iload / (2*.012)) + .25 * Iload] / Iload

Apparently the internal ionic and electronic resistance total is about .25 ohm

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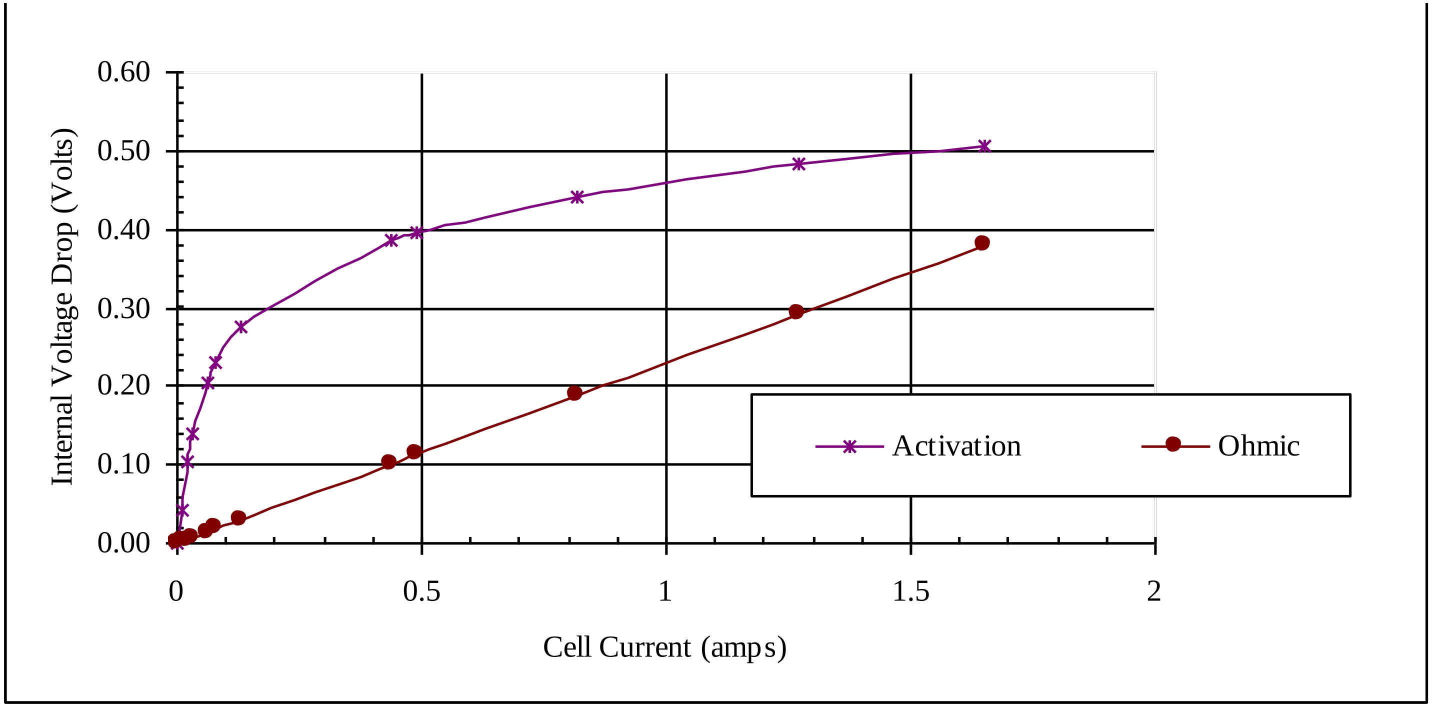

Linear scale plot of contributing parts of internal voltage drop vs. current

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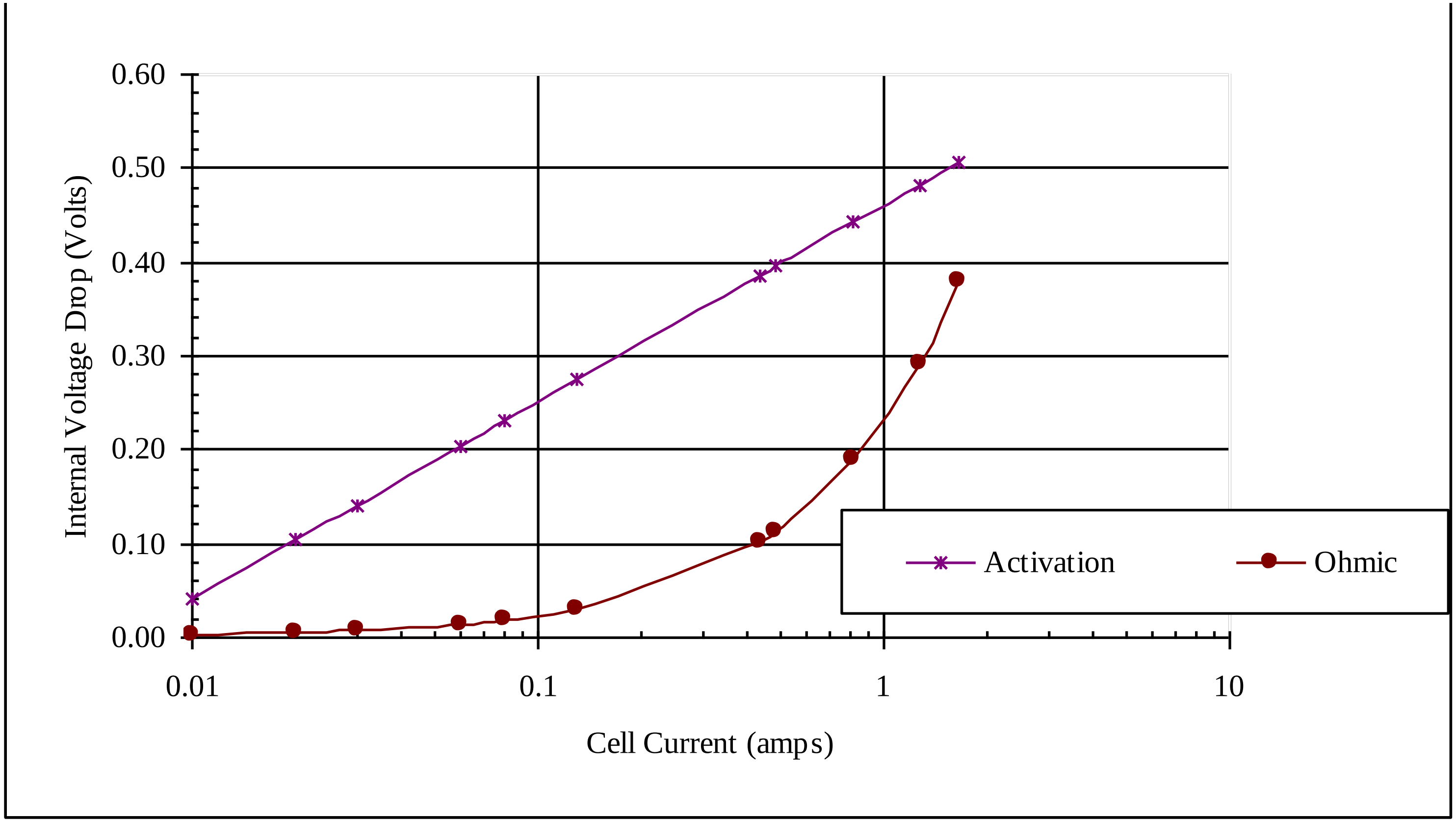

Log scale plot of contributing parts of internal voltage drop vs. current

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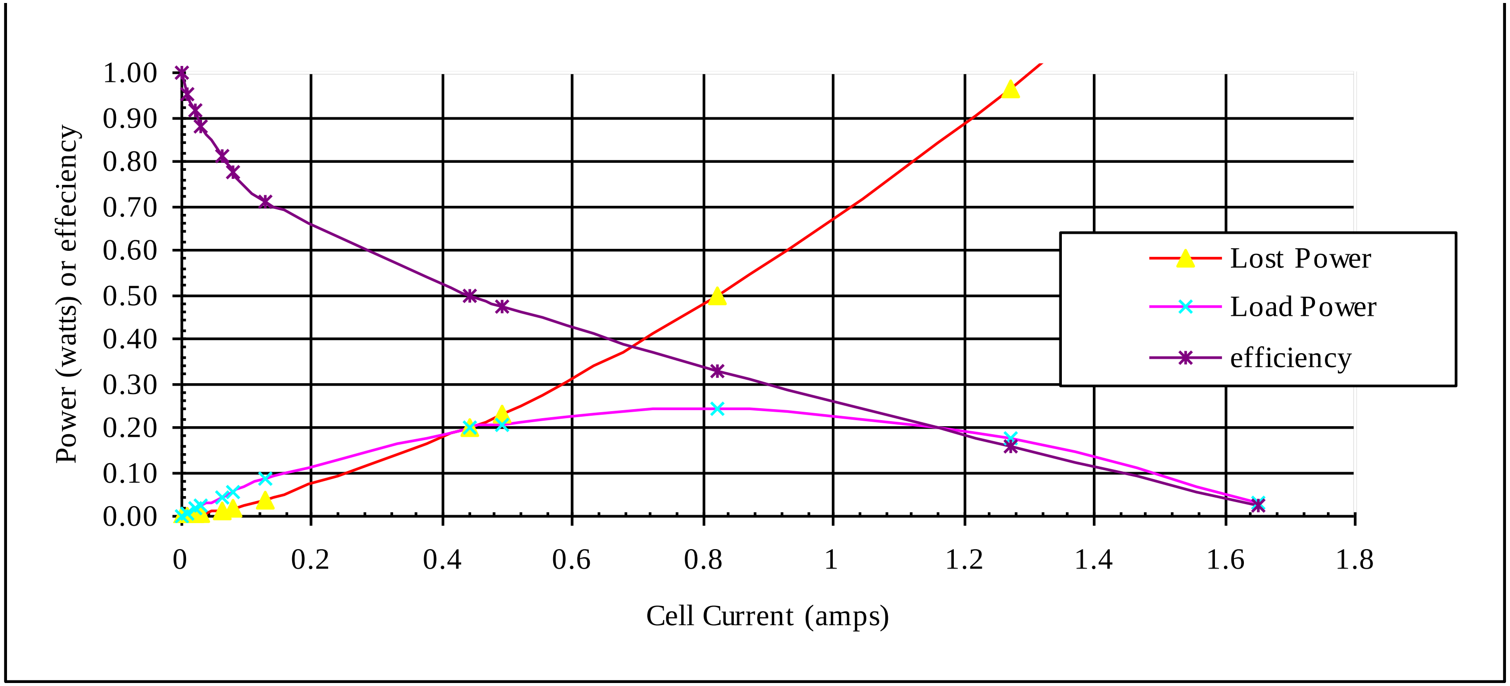

Typical load and internal lost power and efficiency Curves

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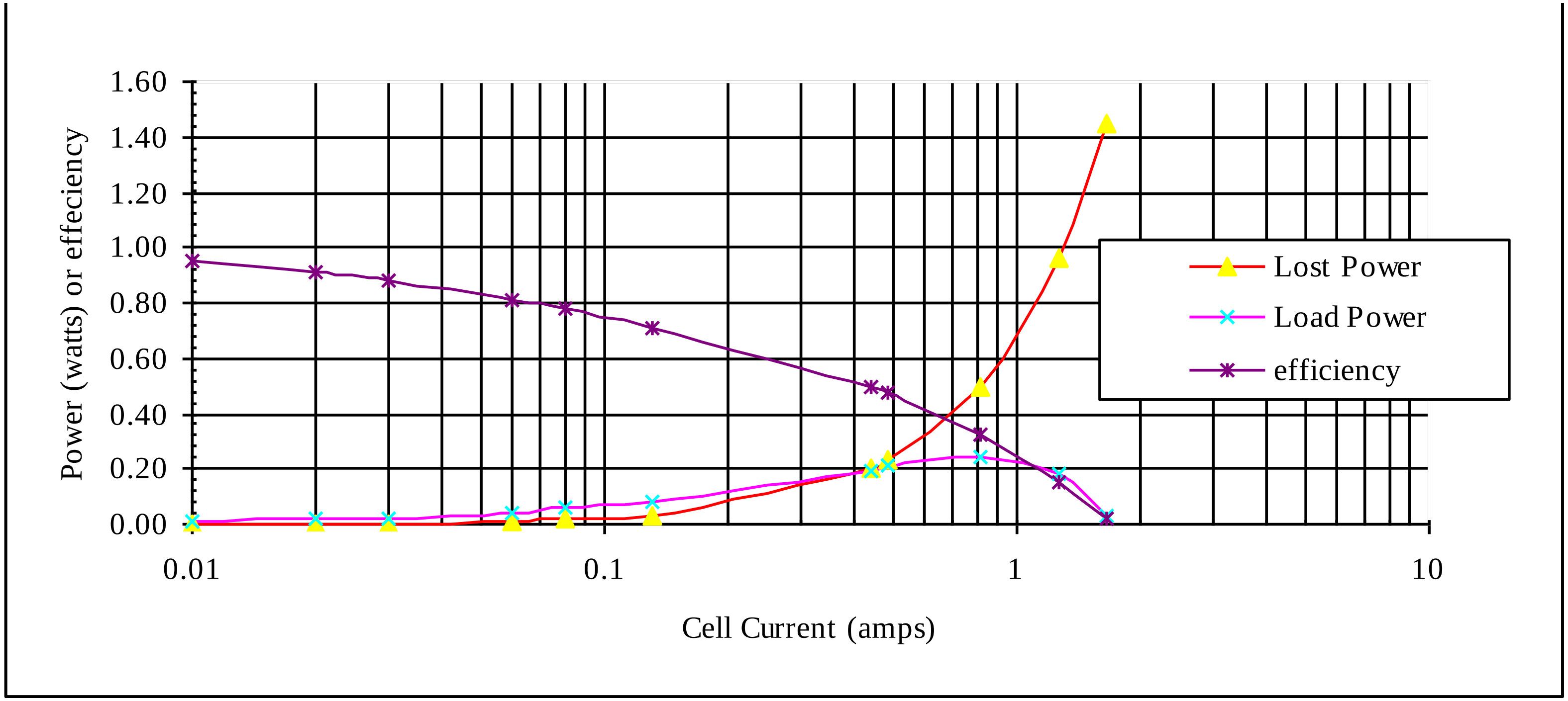

Typical load and lost power and efficiency curves - log-linear scale

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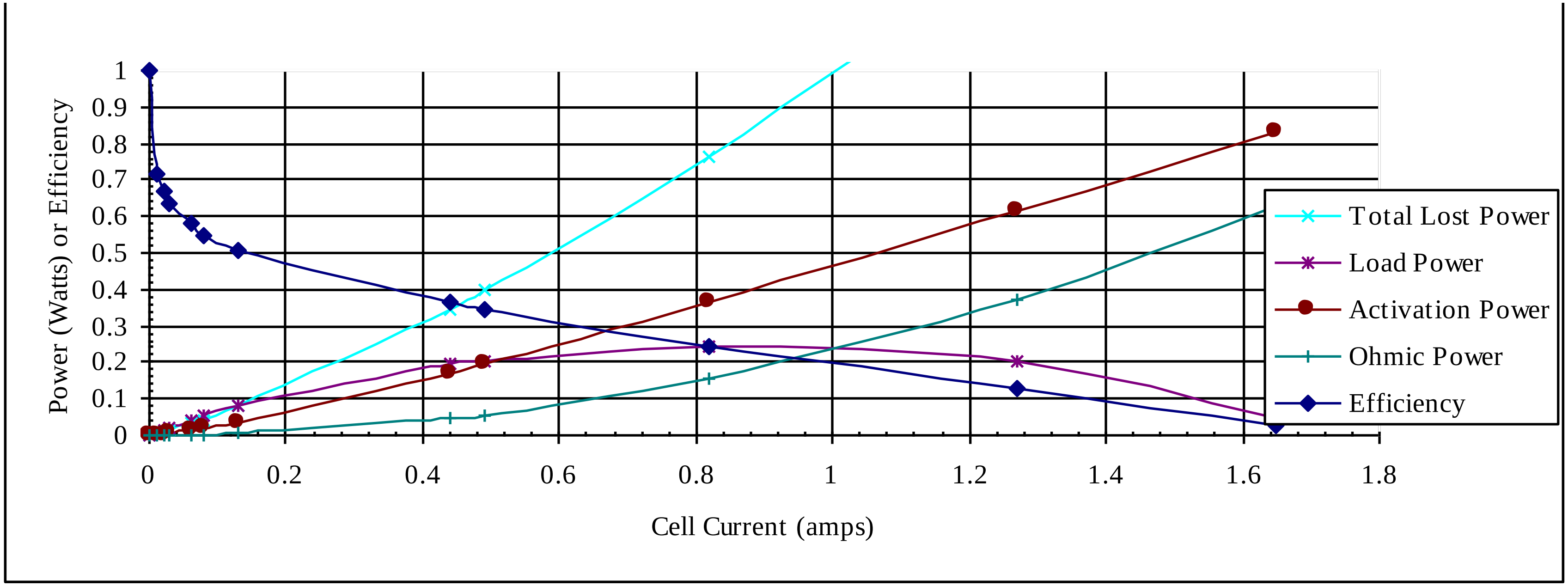

Breakdown of typical internal power loss & efficiency vs. current – linear scale

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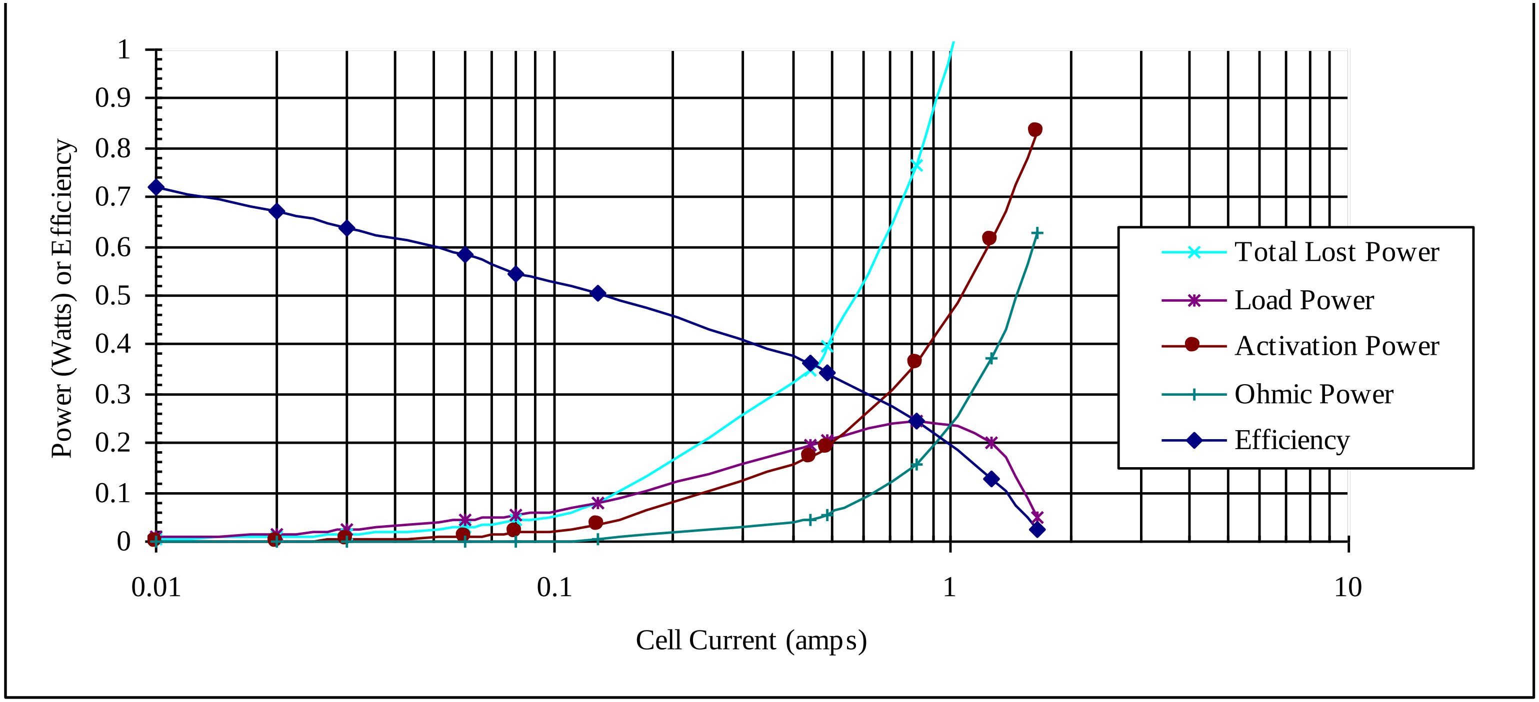

Breakdown of typical internal power loss & efficiency vs. current – log-linear scale

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Conclusion

1. Incremental resistance (- d(v) / d(i)) should not be used

2. Simple circuit models based on the classic Butler-Volmer equations seem to model actual cell behavior quite well over two decades of output current

3. Use of the model equations allows a useful deconstruction of cell polarization curves. This, in turn, allows power loss from several principal mechanisms to be estimated with reasonable accuracy

4. Further work using electrical impedance spectroscopy methods can be used to refine the model presented here.