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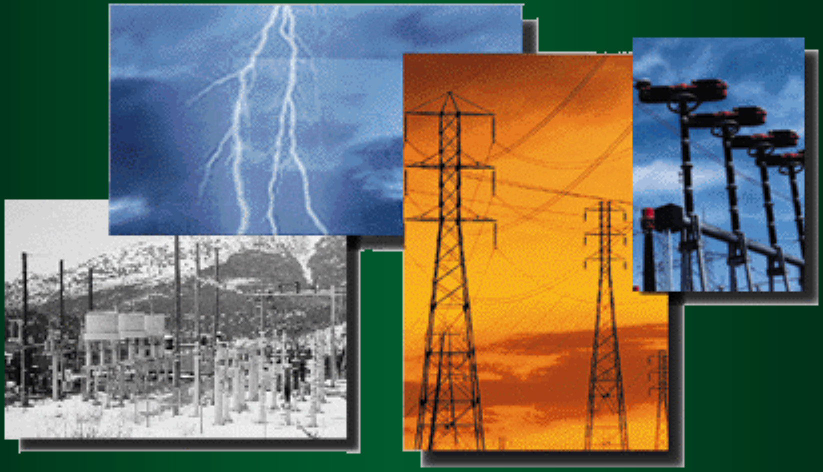
TAMERS OF POWER



IEEE Switchgear Committee Meeting

Condition Monitoring Panel

Pittsburgh, PA

November 11th, 1999

Condition Monitoring and POW Control of Power Delivery Apparatus

Partners in:

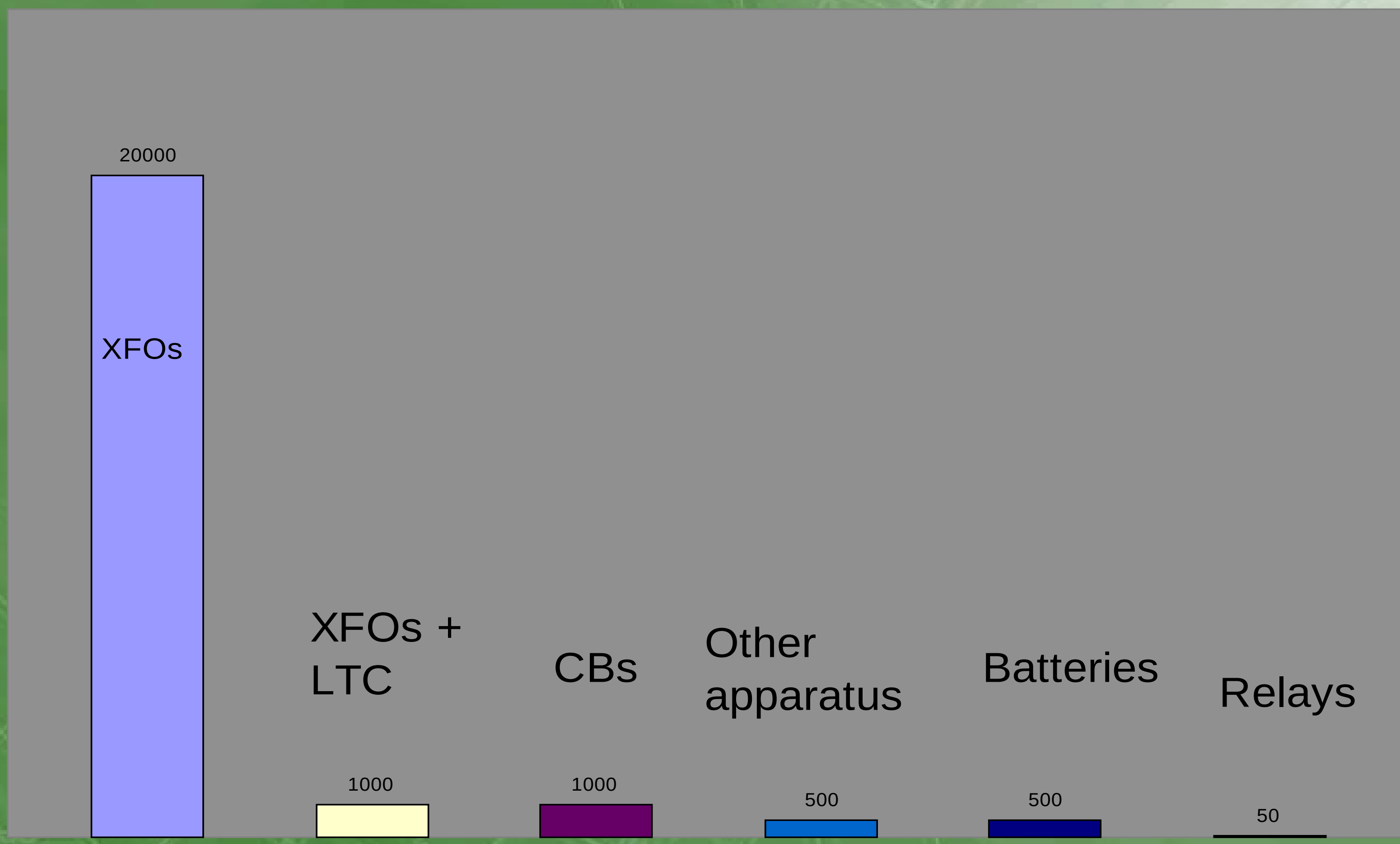
Cost Reduction

Life Extension **Power Quality**

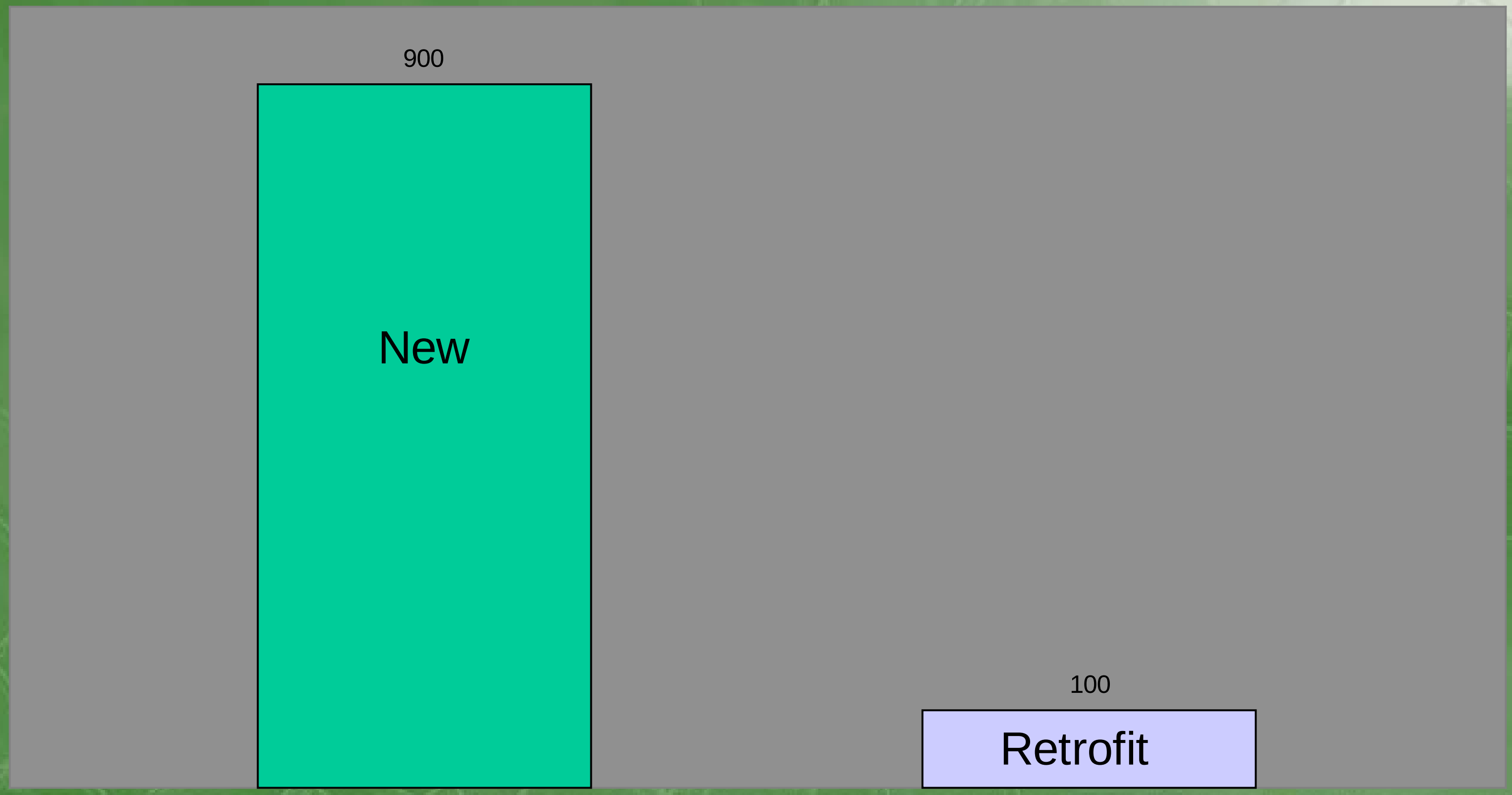
OVERVIEW

- Installed Base and Segmentation
- ROI Methodologies
- Case Studies
- Financial Improvements
- New Designs and Standards

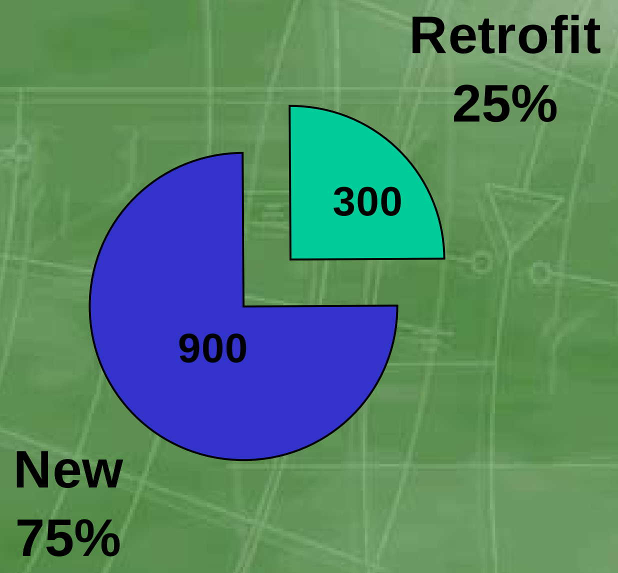
Condition Monitoring Installed Base



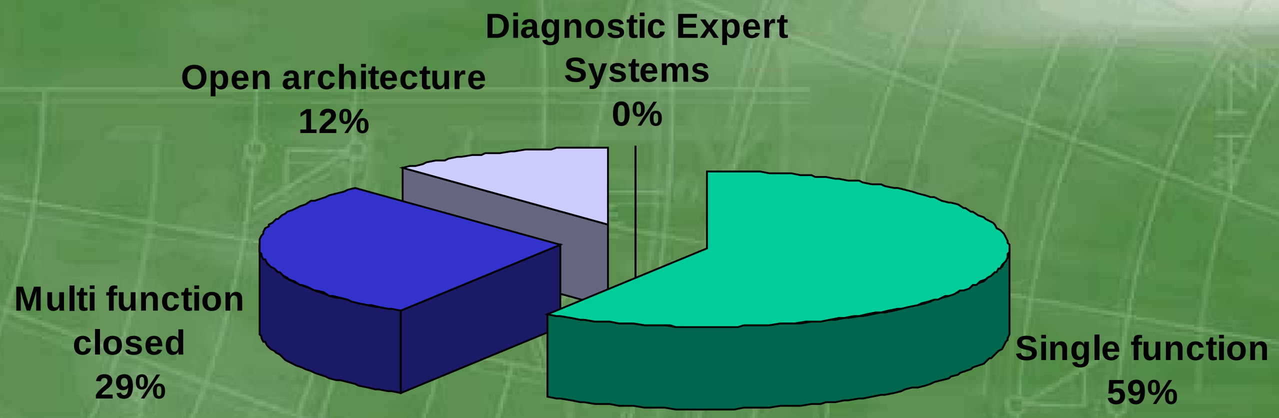
Circuit Breaker Condition Monitoring Installed Base



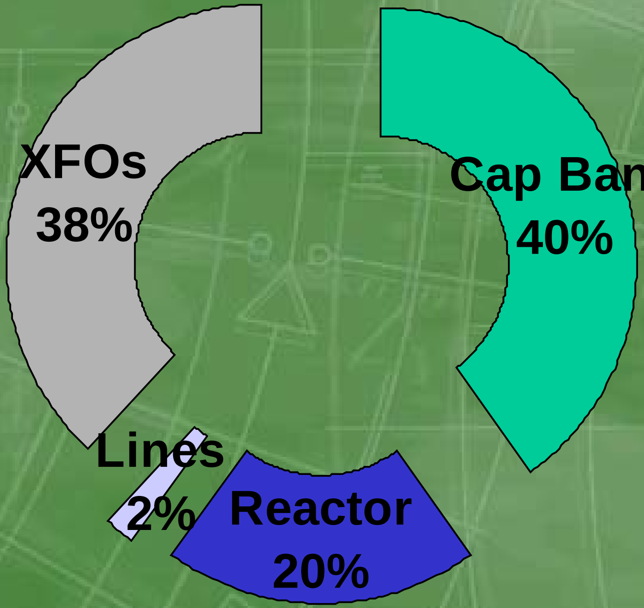
Circuit Breaker POW Control Installed Base



Condition Monitoring Segmentation



Circuit Breaker POW Control Segmentation



ROI Methodologies

ROI Methodologies

$$\text{P}_{\text{redicted}}\ \text{ROI} = \frac{\text{P}_{\text{redicted}}\ \text{S}_{\text{avings}}}{\text{B}_{\text{udgeted}}\ \text{I}_{\text{nvestments}}}$$

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ROI Methodologies

Predicted Savings = Maintenance + Repair + Replacement (w/o CM)

- Maintenance + Repair + Replacement (with CM)

MRR (w/o CM) =

[Budgeted Maintenance + Historical (R+R)] x Years

ROI Methodologies

BI = CMS cost + Engineering + Site costs + Response costs

ROI Methodologies

$$\text{Predicted Payback} = \frac{\text{Budgeted Investment (\$)}}{\text{Predicted Savings (\$ / year)}} \text{ Years}$$

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ROI Methodologies

$$\text{CM E}_{\text{fficacy}}\,\text{R}_{\text{equirement}} = \frac{\text{B}_{\text{udgeted}}\ \text{I}_{\text{nvestment (\$)}}}{\text{P}_{\text{redicted}}\ \text{MRR}\ _{\text{(w/o}}\ \text{CM)}}\ \%$$

ROI Methodologies

Breaker Retrofit

BENEFITS	ABPB ¬	COSTS	Per breaker	Per substation	Per group
Reduction routine inspections costs		Monitoring system hardware and software			
Reduction overhaul costs (postponed and optimized)		Breaker specific engineering			
Reduction in failure costs		Components + cabling installation			
Benefit Index =		Remote communication link installation			
Effectiveness Index =		Sensor + controller sub-system commissioning			
PAFS -		Sensor + controller sub-system maintenance			
Reduction in data analysis costs		Substation staff training			
Reduction in spare parts cost		Substation spare parts			
Increase of revenues		Central controller hardware and software			
Reduction in capital and/or expense costs of equipment		Central controller installation			
Reduction in training costs		Central controller software configuration and commissioning			
Reduction in insurance premiums		Breaker group generic engineering			
Reduction in environmental protection and clean-up costs		Breaker group expert system software			
Reduction in designed redundancy costs		Training			
		Spare parts			
TOTAL BENEFITS		COST SUBTOTALS			

¬ Annualized Benefit Per Breaker

- Projected Annual equipment Failure expenditure Saving

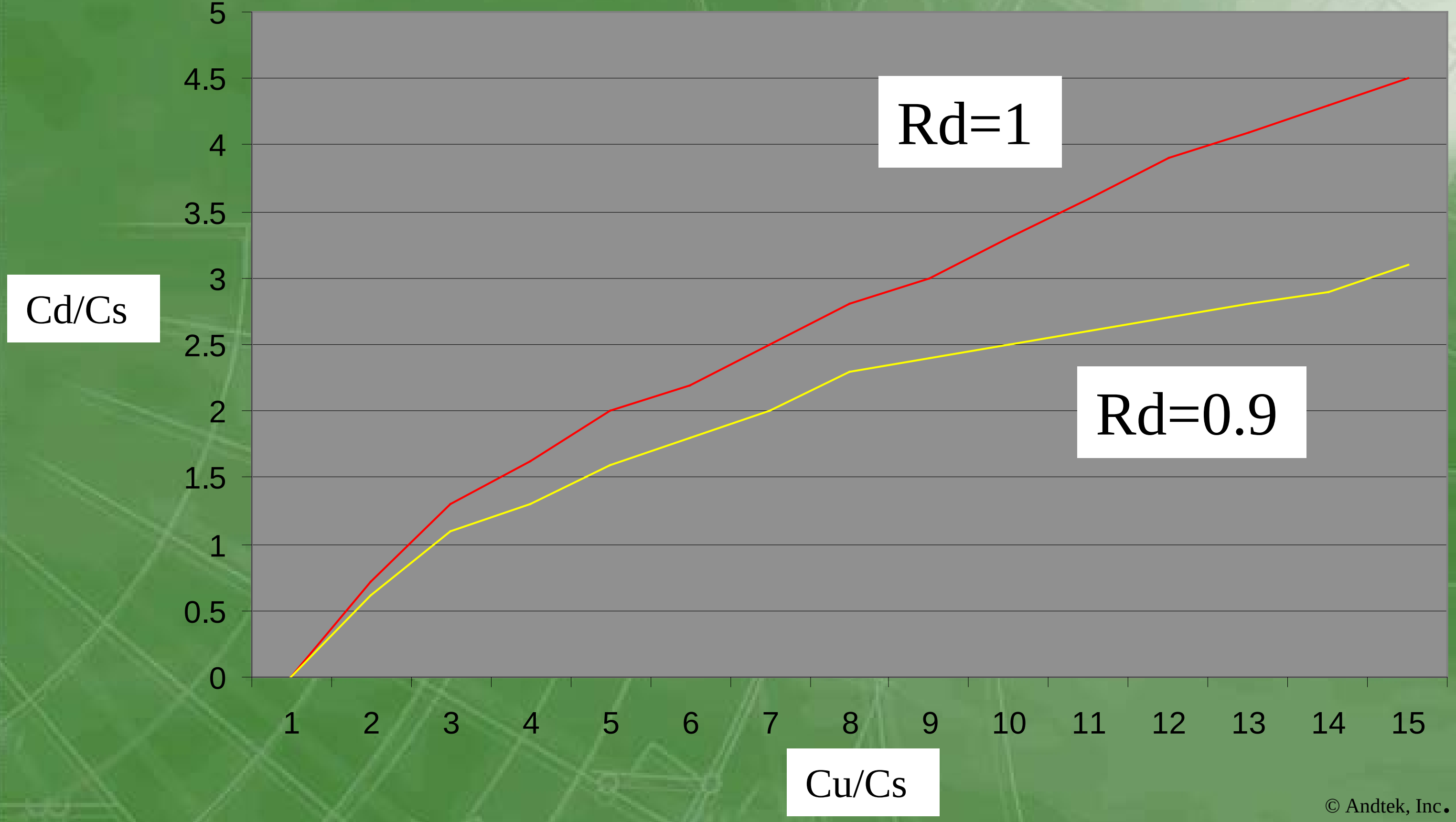
ROI Methodologies

- C_u = Unscheduled renewal
- C_s = Scheduled renewal
- X = Cu / Cs
- T = Period of optimal renewal
- C_d = Diagnostics
- R(t)= Reliability of equipment
- R_d = Reliability of detection

ROI Methodologies

$$\frac{C_d}{C_s} < \frac{\int_0^{\infty} R(t)\,dt}{\int_0^{T} R(t)\,dt} \left[R(T)(1-X) + X\right] - 1$$

ROI Methodologies



ROI Methodologies

POW Control

- Case by case
- New vs retrofit
- POW vs Conventional
- Measurable + Qualitative

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ROI Methodologies

Conventional designs

- Purchase + installation + commissionning
- Routine testing
- Preventive maintenance
- Failure triggered replacement costs

ROI Methodologies POW Control System

COSTS

– EPIC

– Characteristics

– Other devices

BENEFITS

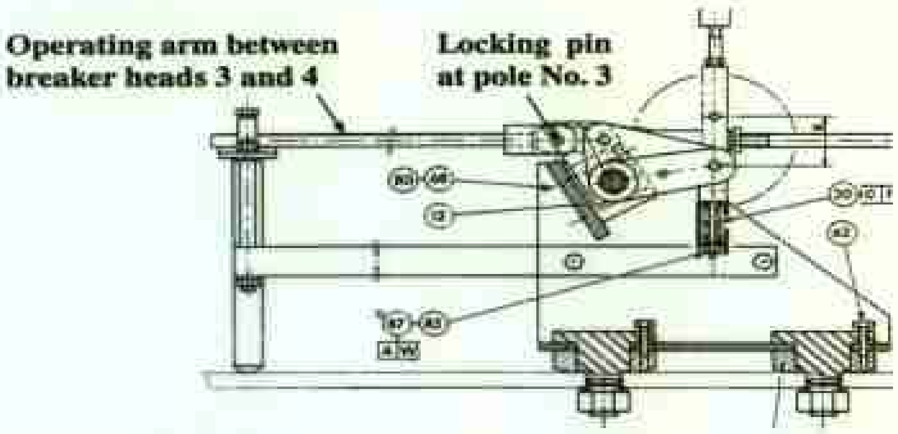
– Savings

– Security

– Power Quality

– Life extension

Monitoring Case Study#1



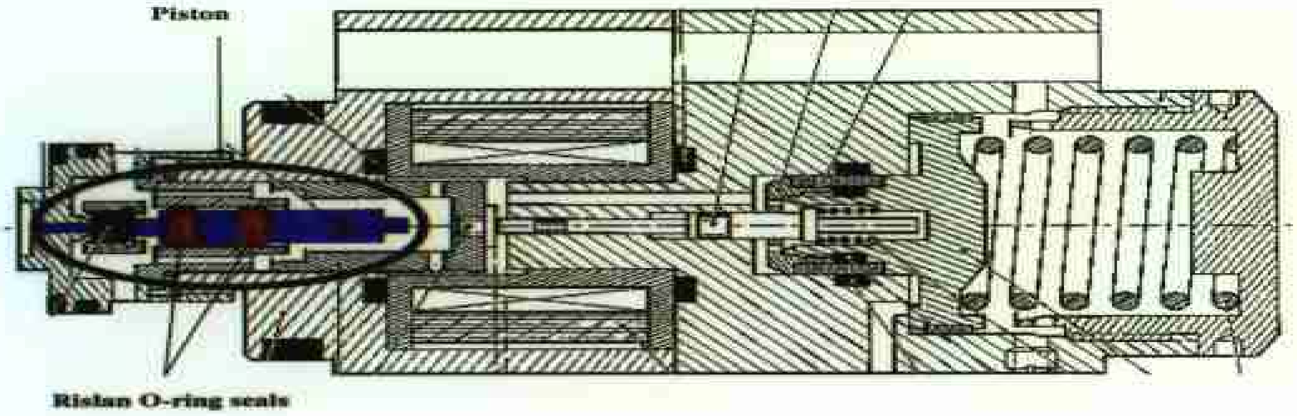
Missing locking pin at pole No. 3 allowed operating arm between breaker heads 3 and 4 to drop out

Load current → No damage

Fault current → Catastrophic

Savings → $ 400,000

Monitoring Case Study#2



Opening electro-valve and piston found jammed in a semi-open position

Locked piston → Explosion

Collateral damage → CT

Savings → $630,000

Monitoring Case Study#3

Pressure drop signature → Stuck moving contact

Fault current → Catastrophic

Savings → $175,000

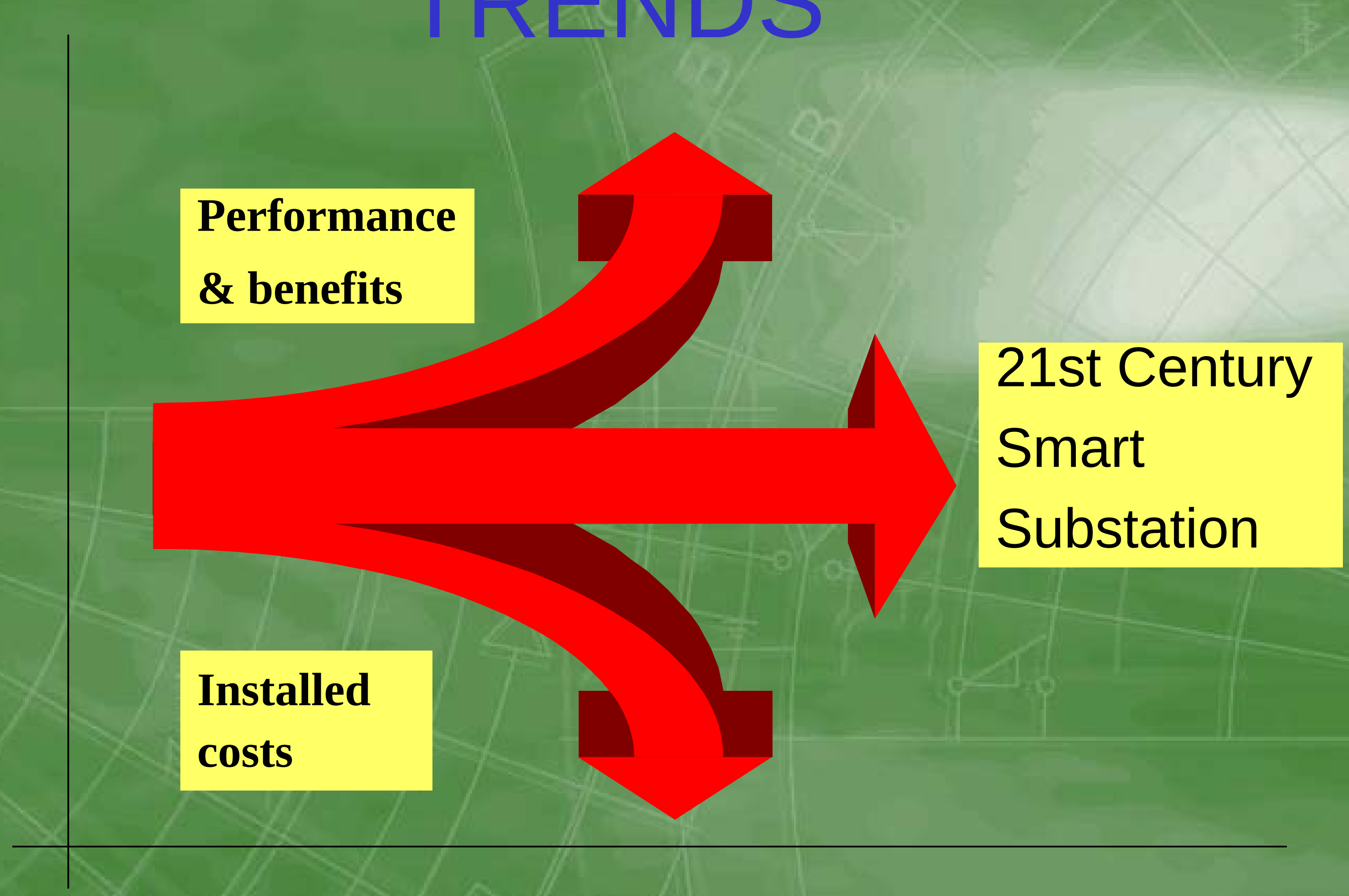
POW Case Study#1

- CEZ
- GSU transformers
- End of life condition
- Historical severe inrush conditions
- Controlled opening to condition remanent flux
- Controlled closing to limit inrush below 30% of rated current
- Deferred purchase > 5 mio $

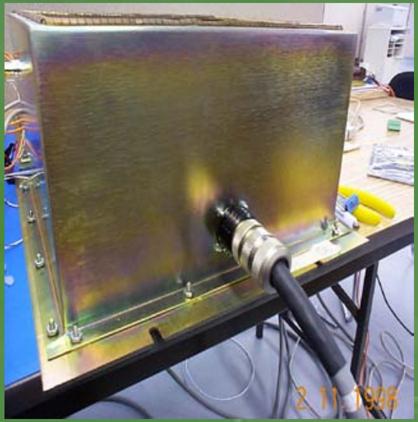
POW Case Study#2

- 25 kV distribution daily Cap bank switching
- O/V trips subway DC supply
- Some passenger cars in tunnels
- Public opinion of Transit Authority and Utility suffers

TRENDS


Performance & benefits
Installed costs
21st Century Smart Substation

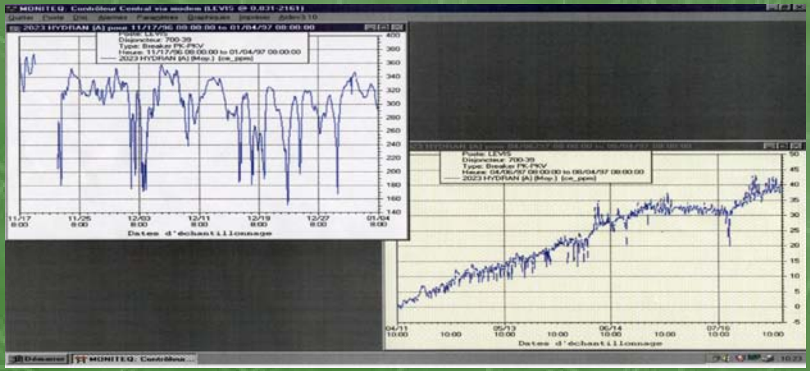
Installed Cost Reductions



CM + POW

2.4GHz Comms

Cabling



Inter-operability

Diagnostic Expert System

DATA

INFORMATION

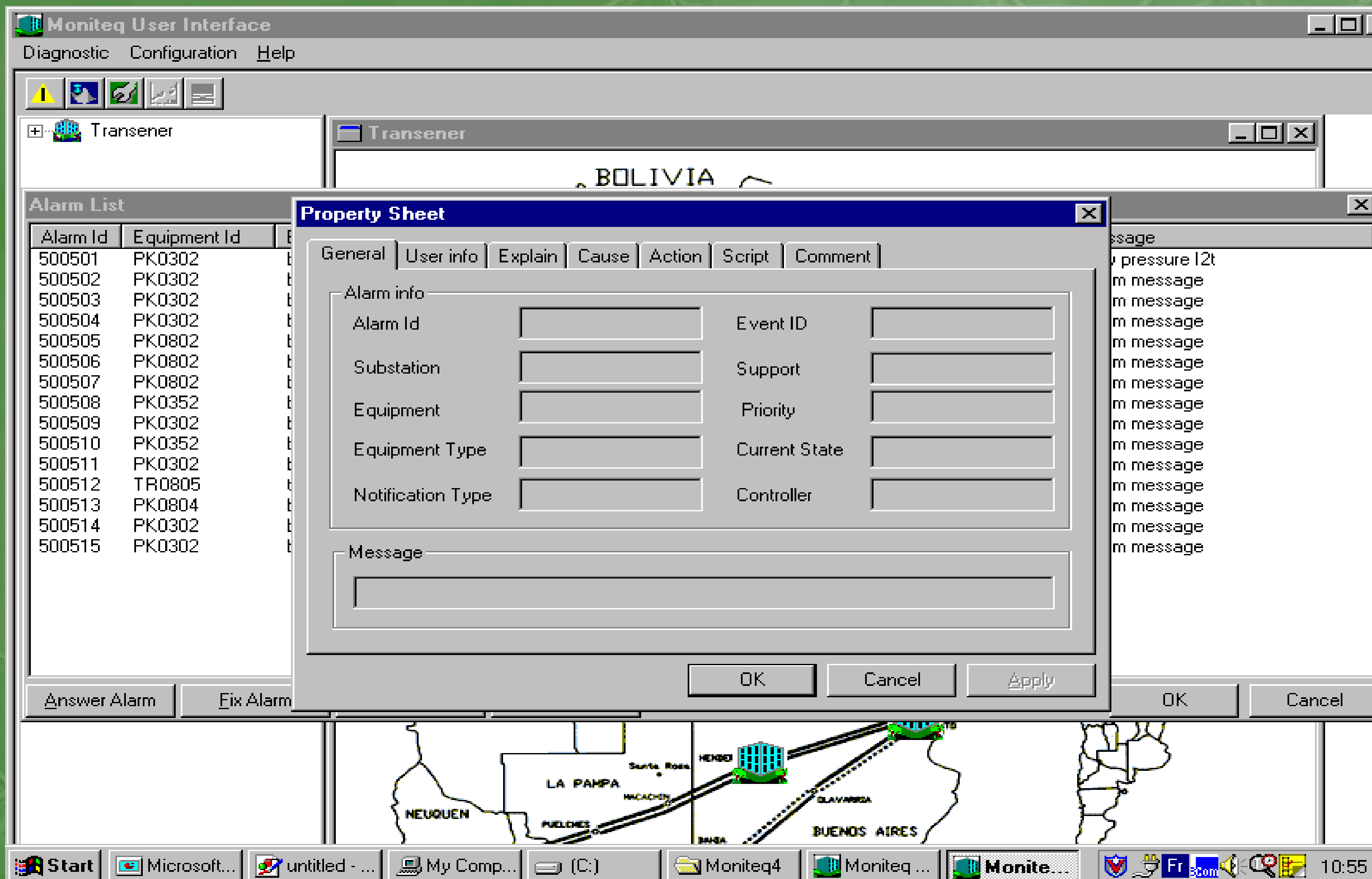
KNOWLEDGE

ACTION

Diagnostics Expert System

- Customized software shell to ensure optimal performance and flexibility
- Device specific rules
- Combinatorial algorithms
- User “tool box”
- Simulation and field tested
- Import / Exportability with other platforms

Diagnostics Expert System



IEC
Interference Immunity

- Electrostatic discharge (ESD) IEC1000-4-2
- Electromagnetic compatibility IEC1000-4-3
- Damped oscillating magnetic fields IEC1000-4-10
- High power, damped oscillations IEC1000-4-12
- Rapid transients (EFT) IEC1000-4-4
- High frequency current, modulated amplitude IEC1000-4-6
- Line conducted transients IEC1000-4-16
- Magnetic fields with energy frequencies IEC1000-4-8, IEC SC 77A

IEC
Emitted Interference

- Main ac current :
- Harmonic oscillation currents and voltage oscillations IEC1000-3-2, IEC1000-3-3

IEC
Climatic Requirements

- Cold temperature IEC 68-2-1
- Dry heat IEC 68-2-2
- Damp heat IEC 68-2-3
- Temperature cycling IEC 68-2-14

IEC Mechanical requirements

- IEC 68-2-6
- IEC 68-2-27
- IEC 68-2-29
- IEC 68-2-59
- IEC 536
- IEC 529 IP 54
- IEC 707

DC Supply Voltages IEC 694

IEC

- IEC 77/215

  EMC Immunity for power stations and substation environments

- IEC 61850-1

  Communication Networks and Systems in Substations

CIGRE

- **WG 13.07 : Controlled Switching**
  - Tutorial (1996)
  - Application Guide (1998)
  - Studies, Specifications and Tests (1999)
- **WG 13.09 : Condition Monitoring**
  - Application Guide (2000)
- **WG 13.10 : Asset Management**

THANKS YOU FOR YOUR ATTENTION

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