Reliability 2003

Power System Reliability
- Case Studies

Authors Mick Drew and Marcus Punch
ARMS Reliability Engineers Pty Ltd.
mdrew@reliability.com.au

www.globalreliability.com

The Business Cost of Power System Unreliability

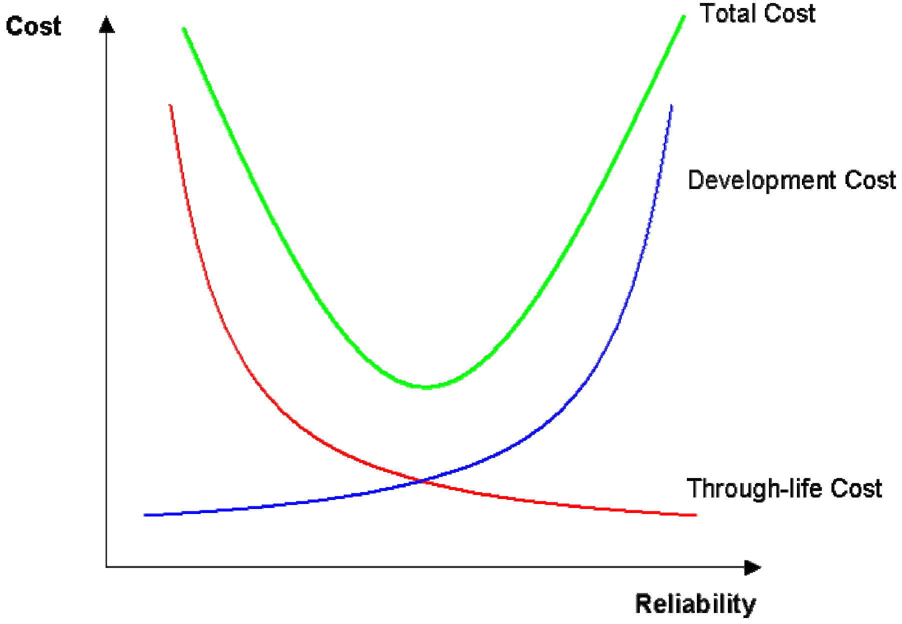
The Challenge

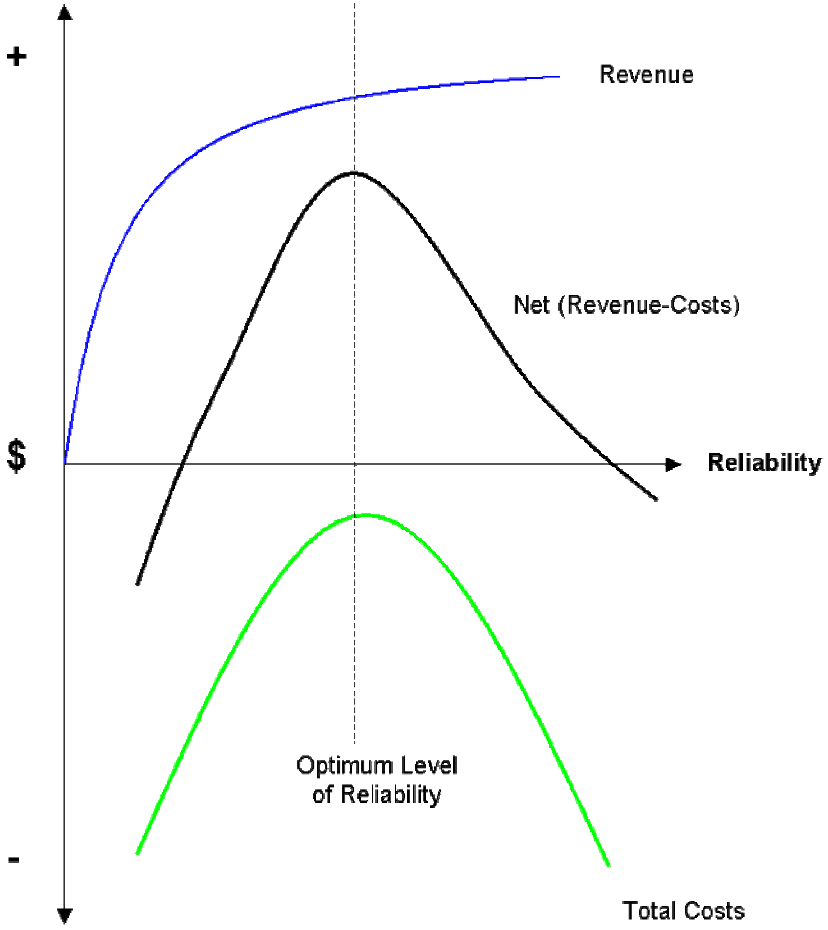
Find the Reliability V's Cost trade-off.

Two Case studies:

1. Industrial Power User.
2. Power Generator.

The Reliability / Cost Tradeoff





Case Study 1: Industrial Power User 33kv Supply

Unreliability Causes Loss Due To Lost Production.

- Cost of power outages.

  Average cost of power interruptions for US industrial plants surveyed 1973-1996 was approx. $AUD13000 per MWhr not supplied. – IEEE Std 493-1997.

- Frequency and duration of outages.

  Average restart time following a power outage for US industrial plants surveyed 1973-1996 was 17.4 hrs. – IEEE Std 493-1997.

Case Study 1: Industrial Power User 33kv Supply

Objective

- Model the expected lifetime performance of an industrial 33kV power supply.
- Identify the best opportunities available for system improvement.

Case Study 1:
33kV Supply to Industrial Plant

Model Construction

- A reliability model was constructed using AvSim+. The model was constructed by gathering relevant system information, including:

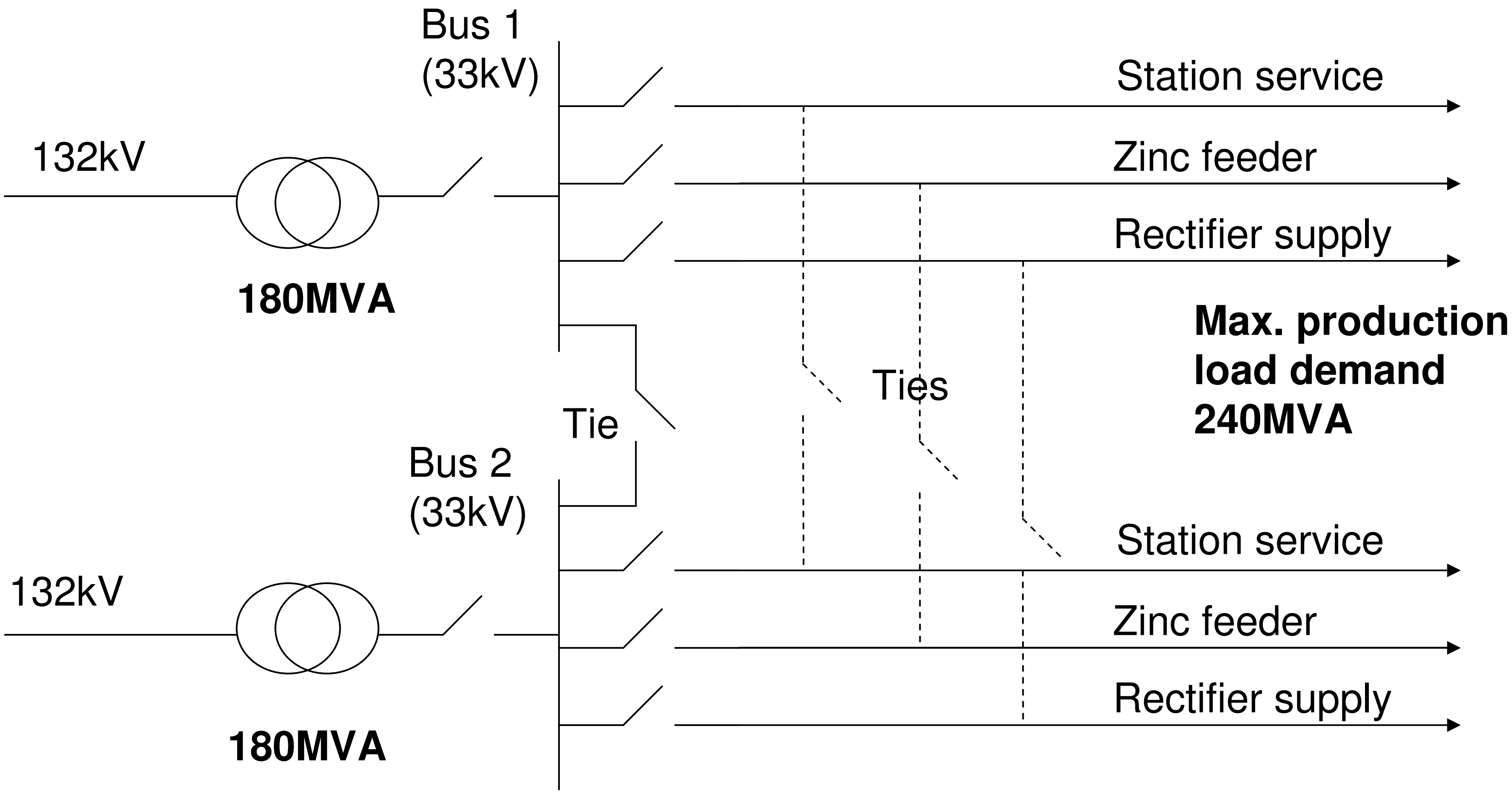
  1. Power system single line drawing;
  2. Equipment capacities and redundancies;
  3. Failure rates and outage durations;
  4. Major maintenance outage schedules; and
  5. Operations and maintenance philosophies.

Case Study 1:
33kV Supply to Industrial Plant

Assumptions

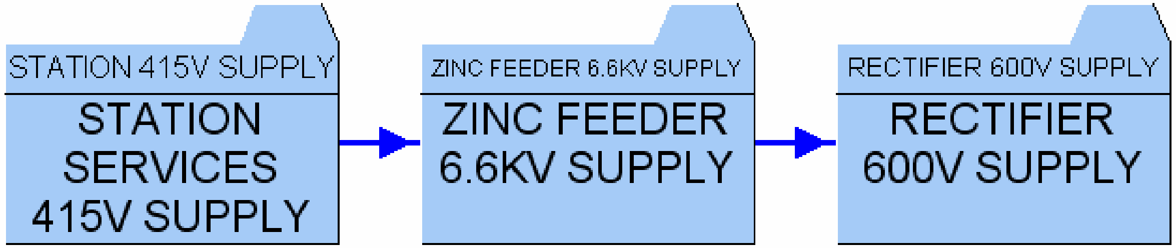
- Failure rates based on IEEE Std 493-1997.
  - These are industry averages for similar power systems.
- Repair times and planned maintenance based on plant history.
- Assign Maximum Production Capacity Impact to Equipment.
  - Based on the individual equipment power requirement for the plant operating at maximum production capacity.

Simplified Single Line Diagram



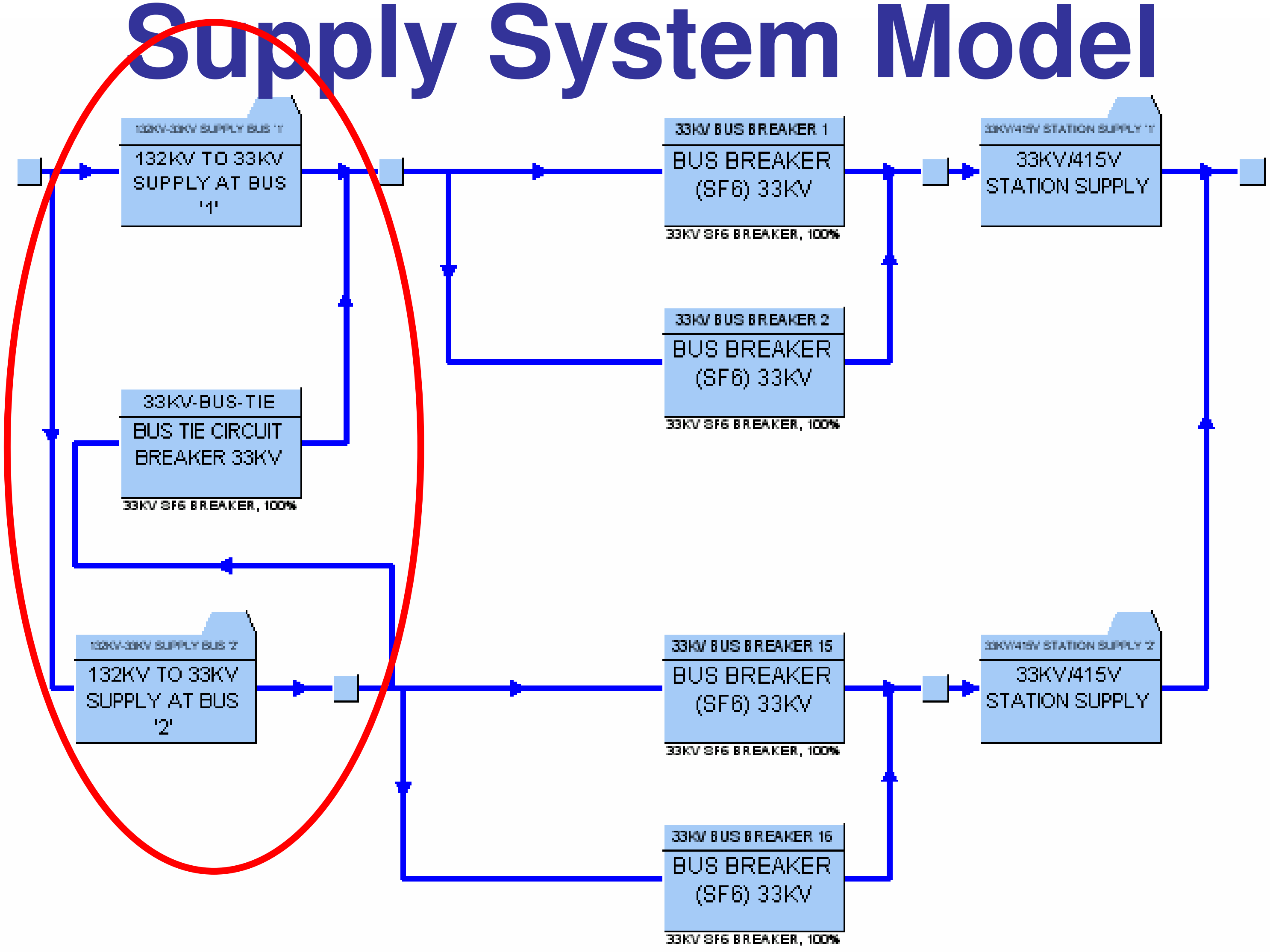
Case Study 1:
33kV Supply to Industrial Plant

RBD Model of Supply



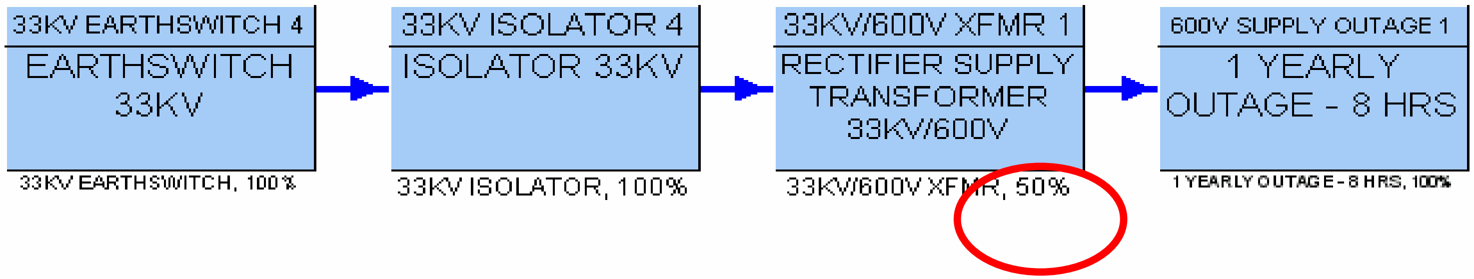
A Separate Network Is Built For Each Essential Supply Service. The Blocks Are Placed In Series As All Three Supplies Are Required For Successful Operation Of The Plant.

Supply System Model



Each Supply Area Is Fed From The Same 132kv/33kv Supply Network. This Network Is Repeated Withiin Each Supply Area So That The Overall Availability Of Each Service May Be Calculated.

Supply System Model



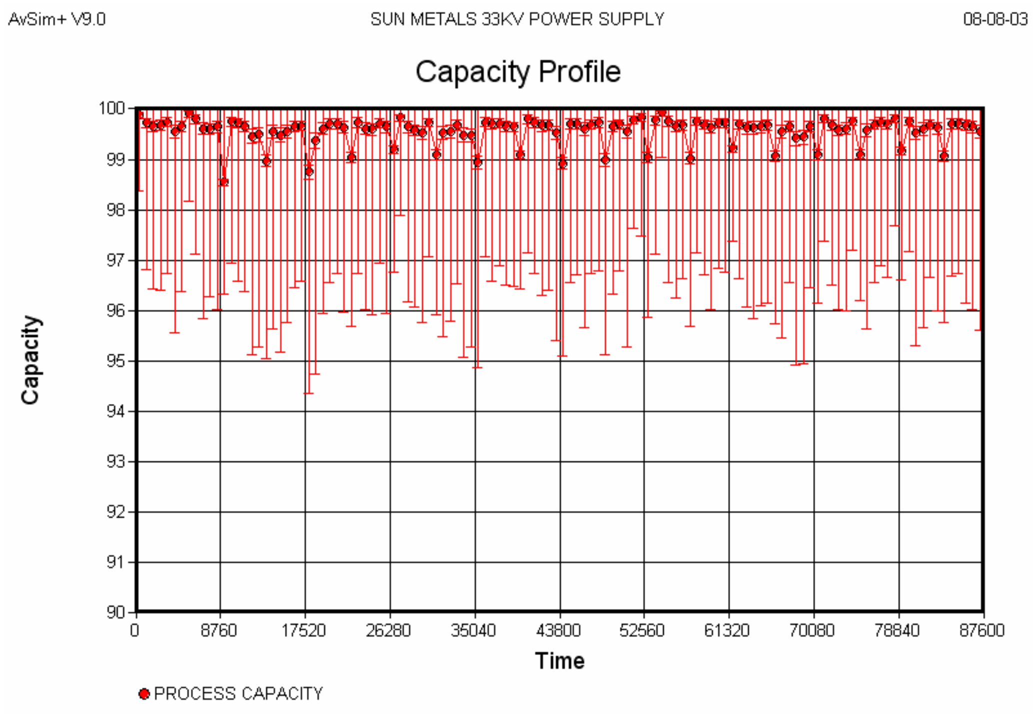
Power demand at rectifiers is 180MVA during maximum production.

Each rectifier feed can supply up to 90MVA.

Each feeder can therefore support 50% of maximum capacity.

Planned outages blocks are also defined to reflect routine maintenance and inspections.

Simulation Results over 10 Yrs



1. The system is capable of supporting an average production capacity of 99.55% of the design maximum production rate over an extended period of time.
2. The capacity profile shows randomness due to constant failure rates, but the relative impact of unreliability of each supply is clear.

System	Capacity Achieved by Each Supply Area (as % of Maximum Production Rate)
Station Service Supply	99.95%
Zinc Feed Supply	99.83%
Rectifier Supply	99.67%
132kV/33kV Supply	99.65%

Acceptability & Options

- What is the 0.45% margin worth?
- What could be improved & how?
- Will improvements deliver dividends?

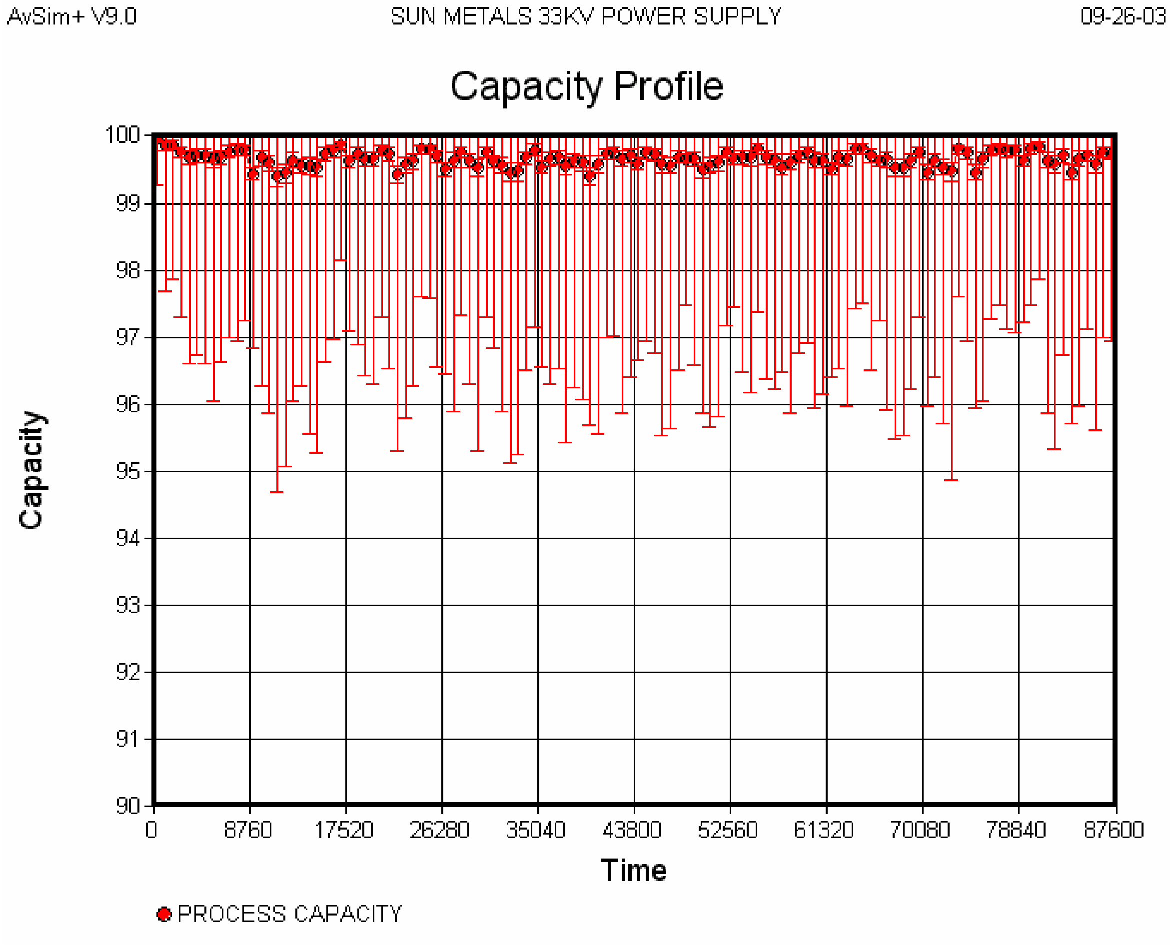
1. Reduce inspection downtime – install condition alarms.
2. Maintenance strategy optimisation – improve reliability & possibly reduce planned downtime.
3. Increase capacity of system components to reduce capacity losses when outages occur.
4. Increase reliability of system components.

<u>All of these options can be modeled !</u>

Test 1: Install condition monitoring

- Install online condition monitoring on transformers and other components.

→reduces planned downtime for annual inspections.



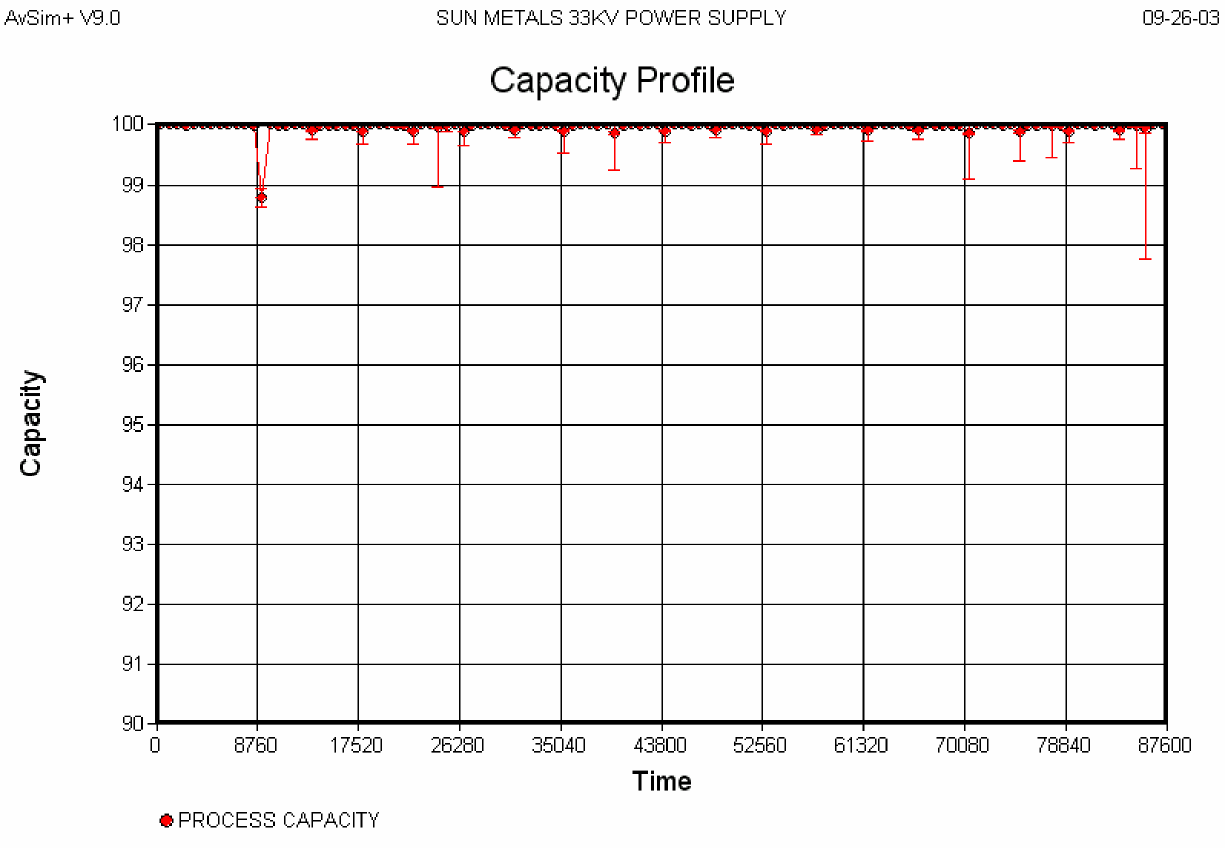
Before: 99.55%

After: 99.66%

Test 2: Increase capacity of components

- Increase capacity of components.

→each feed of each service was uprated to 100% of maximum production demand



Before: 99.55%
After: 99.97%

Case Study 2: Power Supplier

Unreliability Causes Loss Due To Lost Revenue.

- Variability of effects.

  e.g.. Selling power to electricity market – spot price fluctuations $10-$10000 / MWhr.

Case Study 2: Power Supplier

Power converter system.

- Antiquated system, poor support, unreliable.

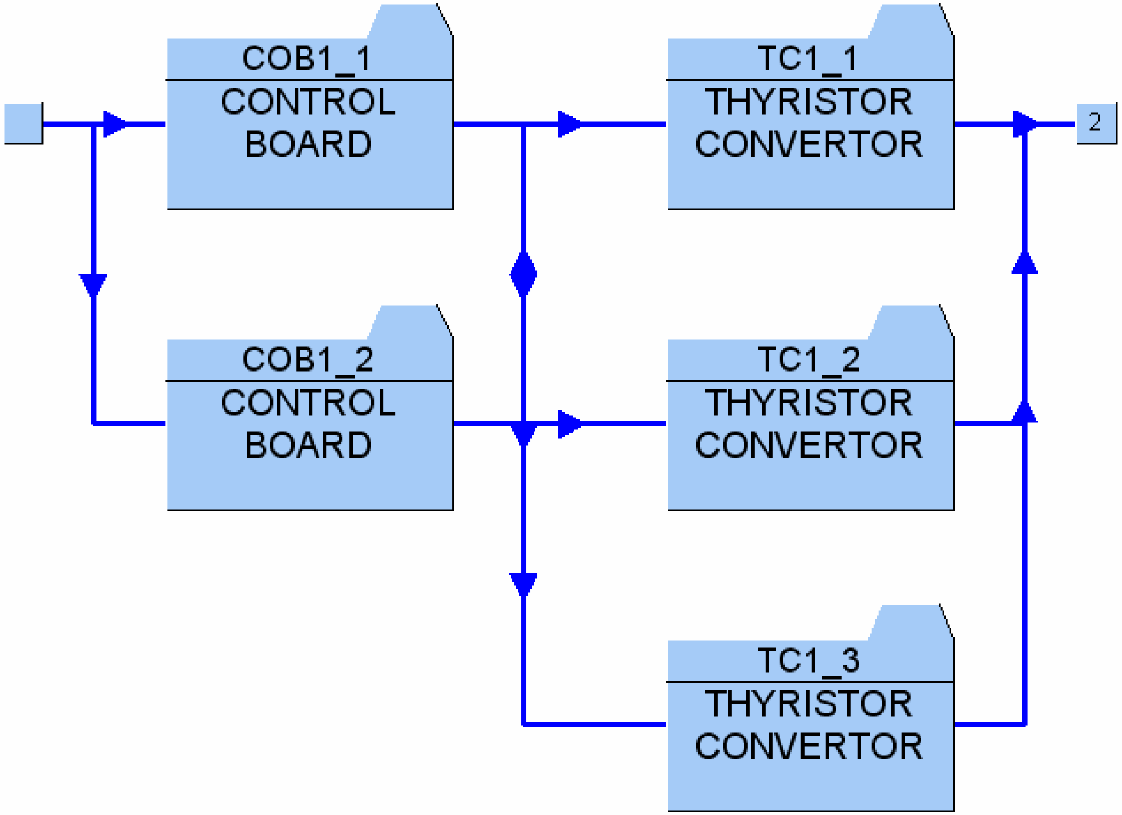
- Call for tenders – replacement system.
- Comparison of reliability, availability and cost between tendered options.

- 6 converter units required.
- 3 design options considered

Case Study 2: Power Supplier

Option 1

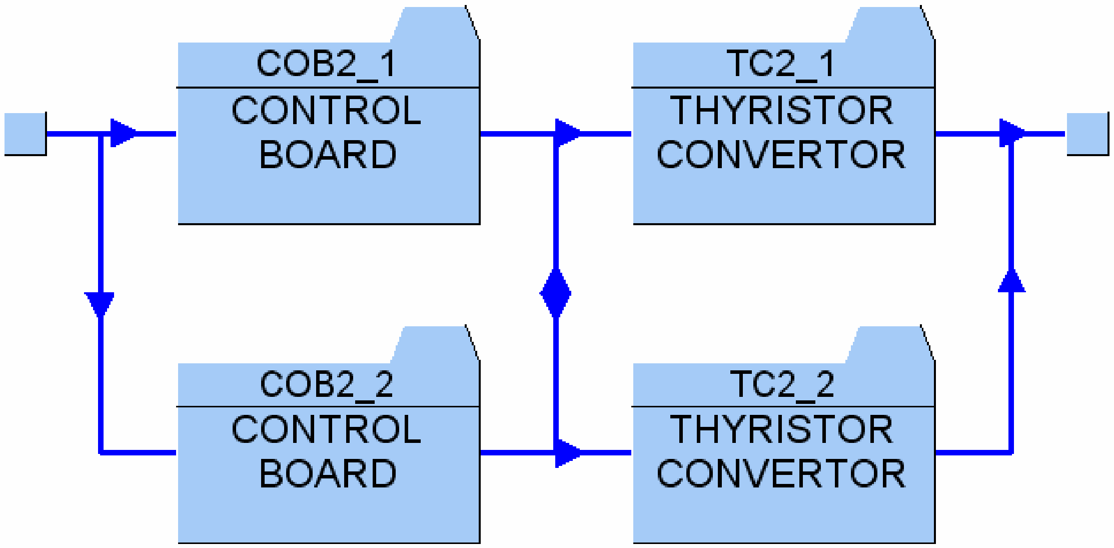
Redundant automatic controls and 2-out-of-3 uncooled converters



Case Study 2: Power Supplier

Option 2

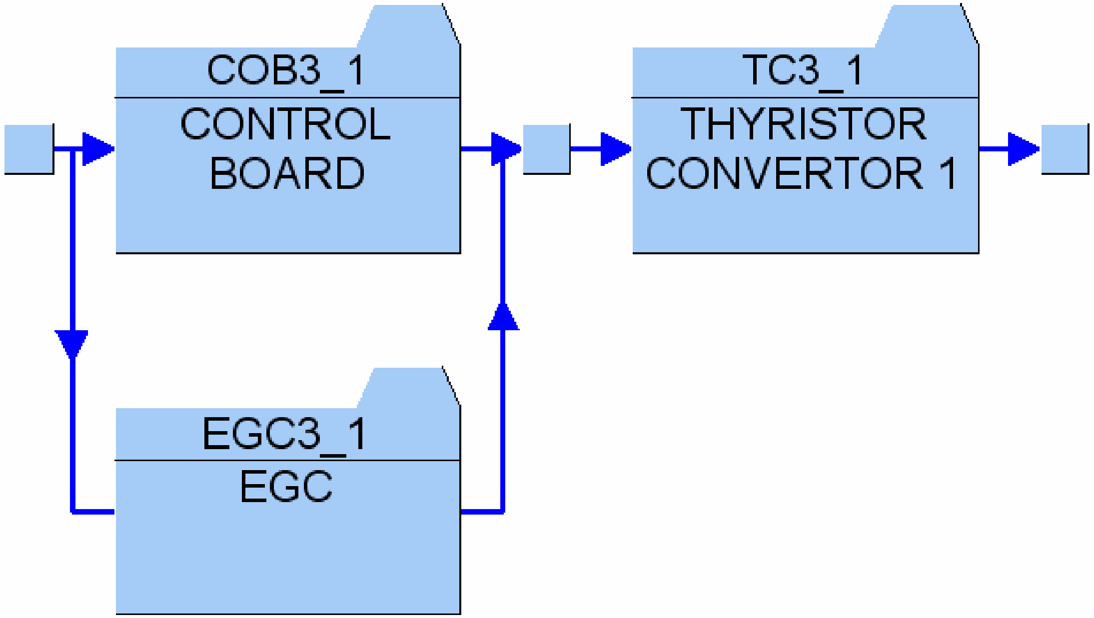
Redundant automatic controls and 1-out-of-2 cooled converters



Case Study 2: Power Supplier

Option 3

Single automatic control with manual backup and single cooled converter



Case Study 2: Power Supplier

Results

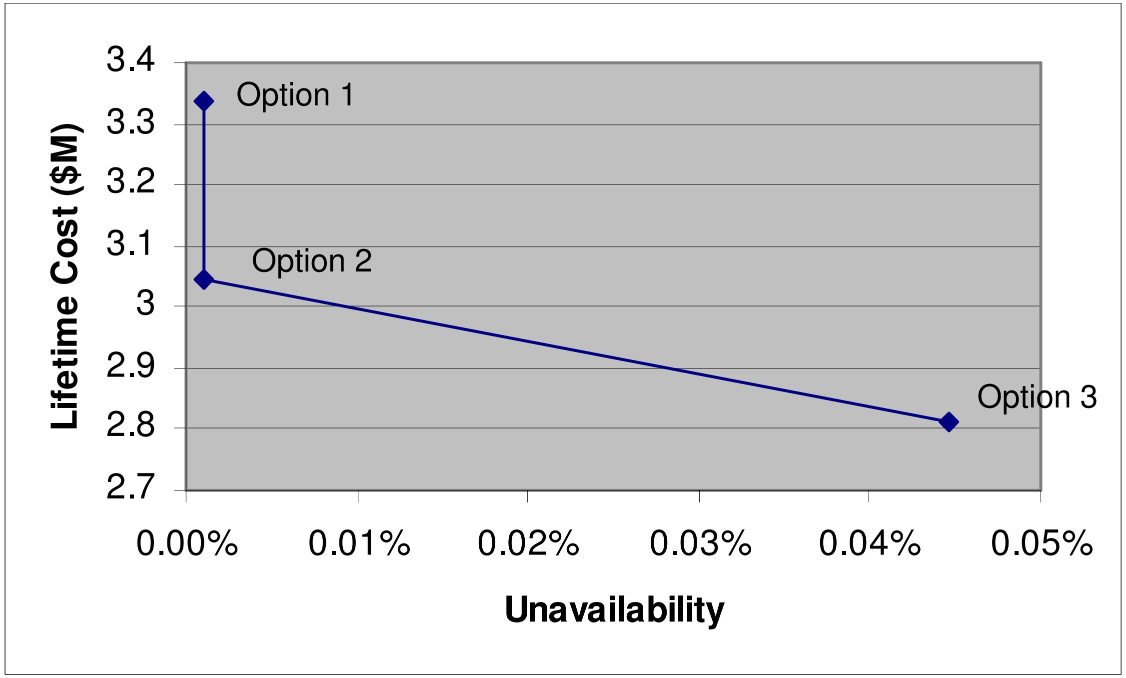
RAMS	**Option 1**	**Option 2**	**Option 3**
Operational Availability (%)	99.9989% per unit	99.9990% per unit	99.9553% per unit
Expected Number of System Failures in 15 yrs	0.01 per unit	0.007 per unit	0.89 per unit

COST	**Option 1**	**Option 2**	**Option 3**
Annual Cost (spares, labour, production losses for 6 generating units)	$27.4k	$30.1k	$42.1k
Capital Outlay (for installation in 6 generating units)	$2.926M	$2.596M	$2.178M

So which option is best ?

Case Study 2: Power Supplier

Reliability V’s Cost Tradeoff



Conclusion

- Quantitative basis for comparing the performance of design options against costs of unreliability.
- Predict performance before the system is built.
- Estimation of lifetime costs, probability of failure and expected downtime.
- Simple, quick, cost-effective analysis.
- Basis for continuous improvement of the design.
- Sound basis to sell the solution to stakeholders.

More Information

- Mick Drew, ARMS Reliability Engineers Pty Ltd. mdrew@reliability.com.au or www.reliability.com.au
- IEEE Std 493-1997 “IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems”.
- Billinton,R., and Allan. R.N.,”Reliability Evaluation of Power Systems”, Plenum Press.