Observations on GSU Transformer Loss Mitigation and Loss Control

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ELECTRIC GENERATION
ISSUES, TRENDS, and PRACTICAL SOLUTIONS

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Why Are Power Transformers Needed?

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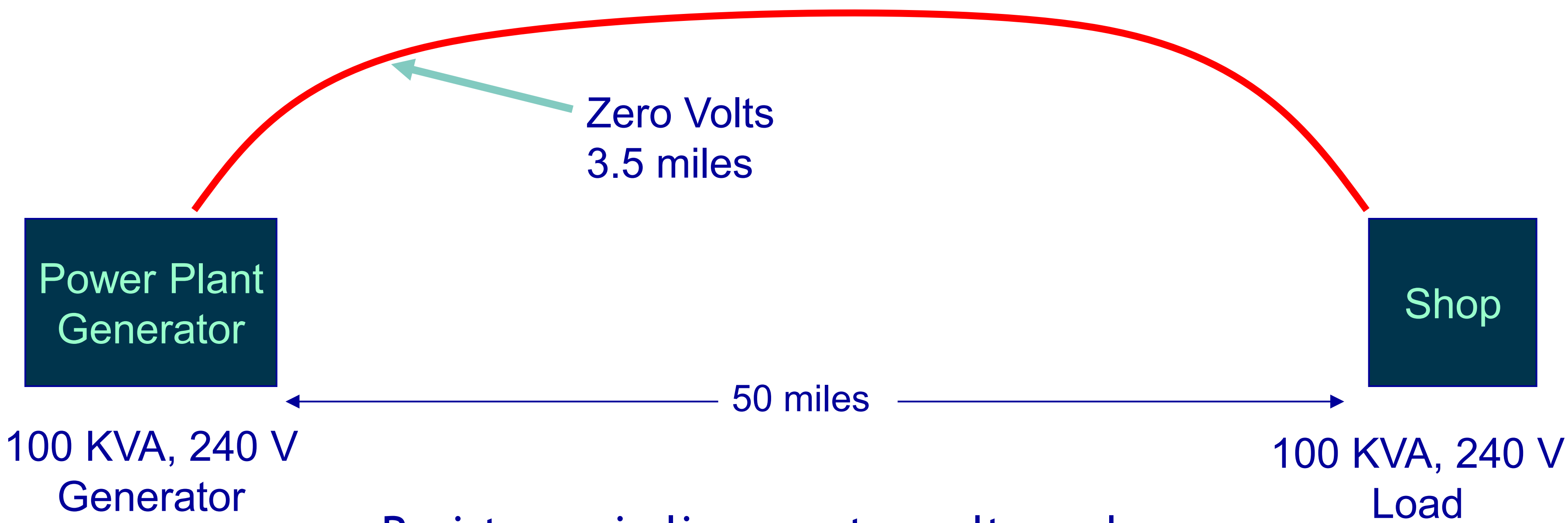
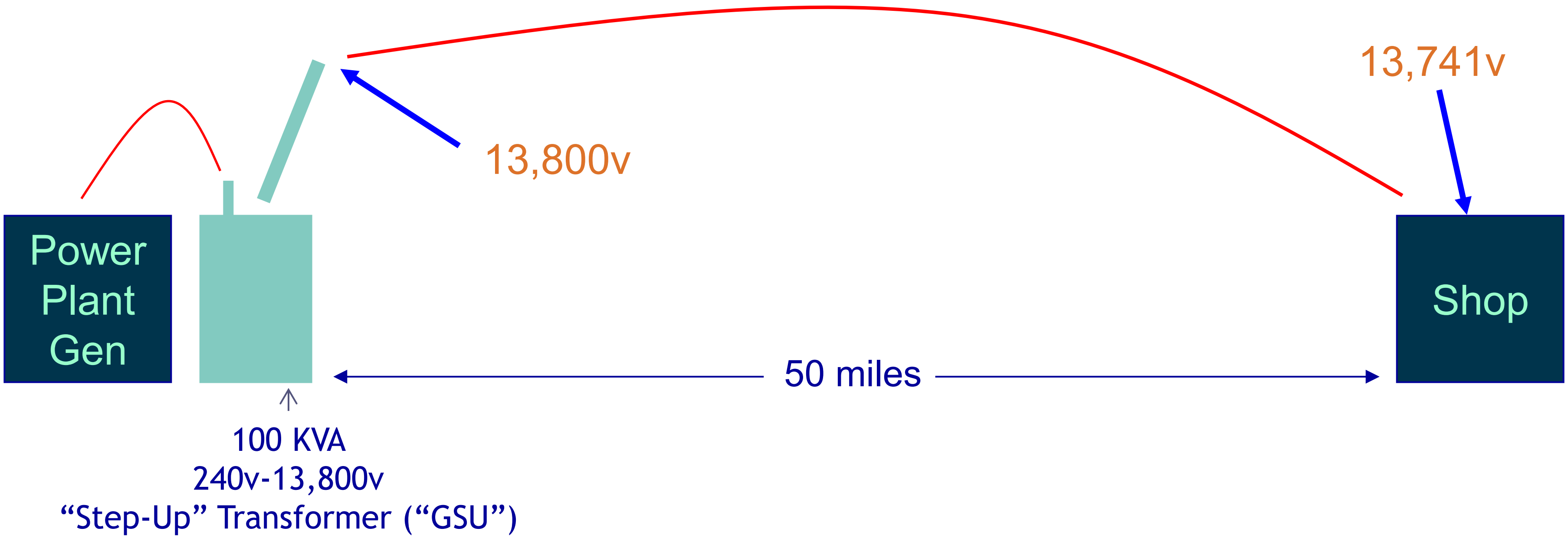
Why Do We Need Transformers?
(Why not generate at 240v?) Answer: Resistance



Resistance in line creates voltage drop
Ohms Law V = R*A

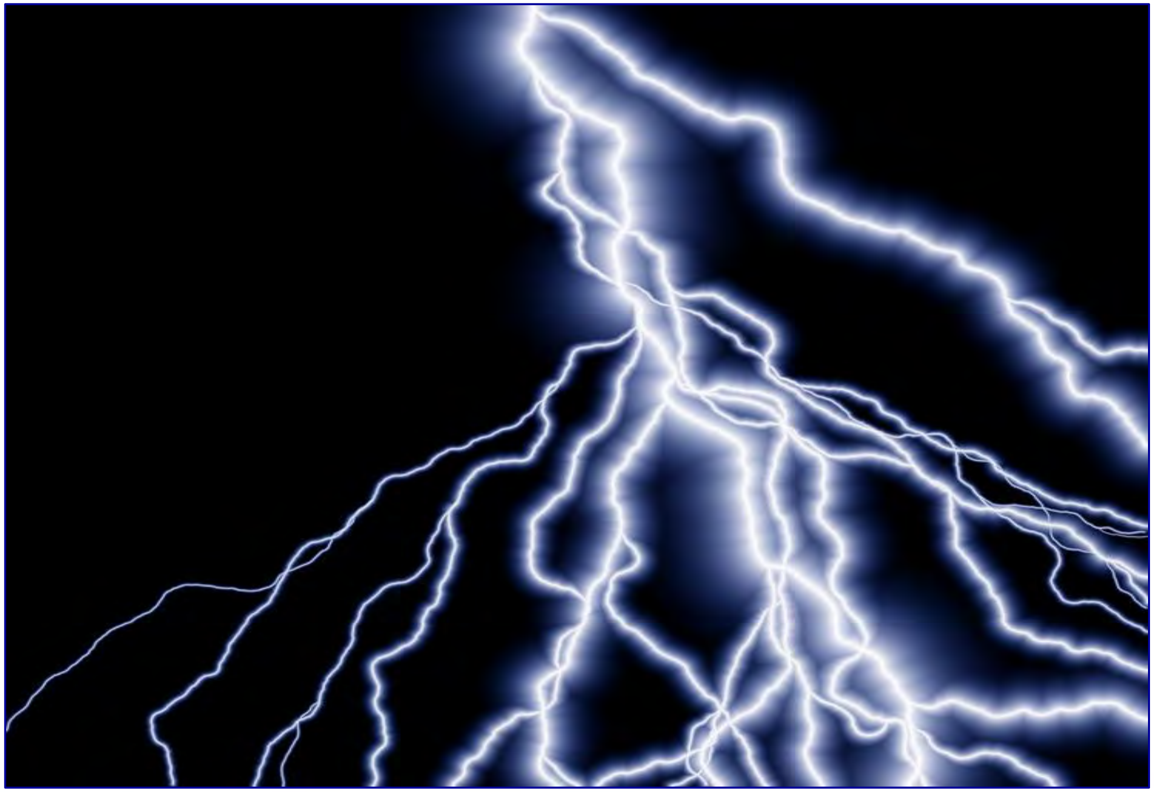
Why Do We Need Transformers?

Use a transformer to “step-up” generator voltage to 13,800 V



We have solved the problem of a voltage drop - A GSU Transformer will be used to increase the voltage at the source. However, we have another issue - One cannot run a compressor etc on 13,800 (or 13,741) volts- A “Step-Down Transformer” will be needed to decrease the voltage at the end user’s location.

Power = Current x Voltage



The higher the voltage the lower the current level
for the same amount of power

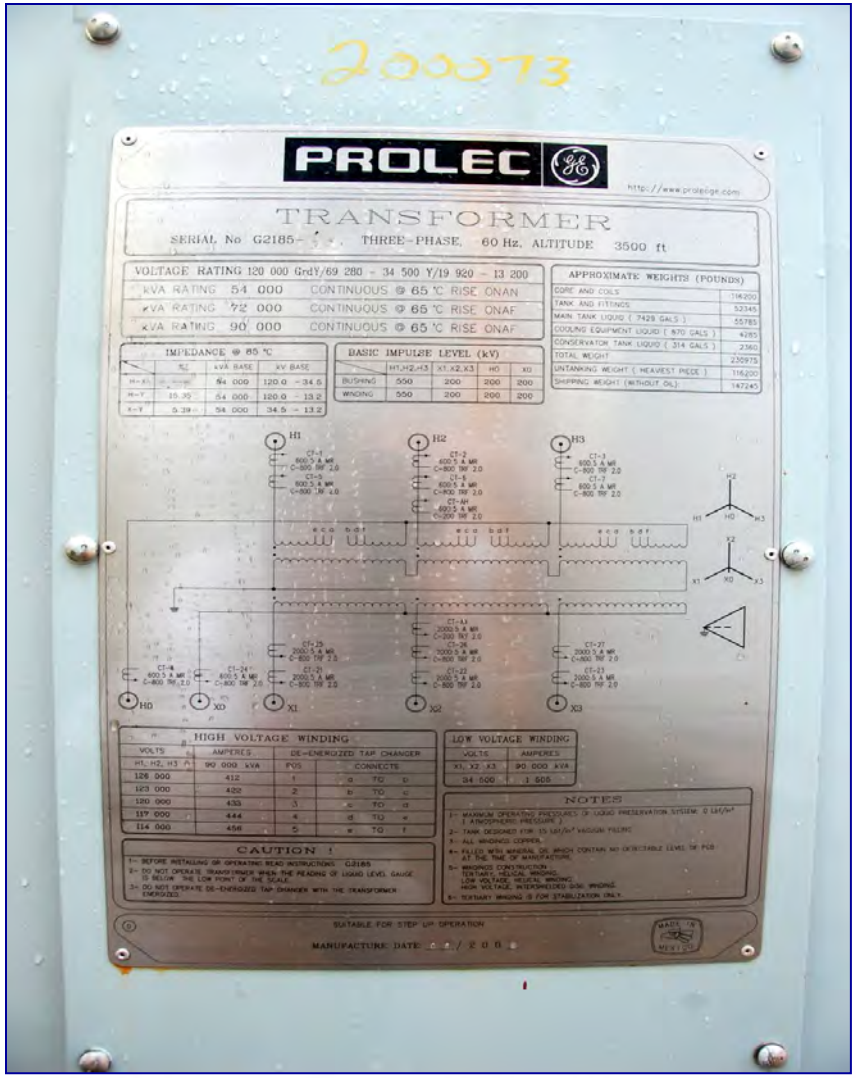
Typical System Voltages

60 HZ (U.S. Std.)

13,800V – 500,000V Generator to Transmission
500,000V - 34,500V Transmission to Sub-Transmission
138,000V – 13,800V Sub-Transmission to Distribution
13,800V – 120/240V Distribution to Residential or Commercial Use

50 HZ- (European Std)

11,500V – 400,000V Generator to Transmission
400,000V - 33,000V Transmission to Sub-Transmission
132,000V – 11,500V Sub-Transmission to Distribution
11,500V – 380/208V Distribution to Residential or Commercial Use


200073
PROLEC
TRANSFORMER
SERIAL No G2185- THREE-PHASE 60 Hz ALTITUDE 3500 ft
VOLTAGE RATING 120 000 GrdY/69 280 - 34 500 Y/19 920 - 13 200
kVA RATING 54 000 CONTINUOUS @ 65 °C RISE ONAN
kVA RATING 72 000 CONTINUOUS @ 65 °C RISE ONAF
kVA RATING 90 000 CONTINUOUS @ 65 °C RISE ONAF
APPROXIMATE WEIGHTS (POUNDS)
IMPEDANCE @ 85 °C
BASIC IMPULSE LEVEL (kV)
HIGH VOLTAGE WINDING
LOW VOLTAGE WINDING
NOTES
CAUTION !

Cause of Transformer Failures

Cause of Failure	Number	Total Paid
Insulation Failure	24	$ 149,967,277
Design/Material/ Workmanship	22	$ 64,696,051
Unknown	15	$ 29,776,245
Oil Contamination	4	$ 11,839,367
Overloading	5	$ 8,568,768
Fire/ Explosion	3	$ 8,045,771
Line Surge	4	$ 4,959,691
Improper Maintenance/ Operation	5	$ 3,518,783
Flood	2	$ 2,240,198
Loose Connections	6	$ 2,186,725
Lightning	3	$ 657,935
Moisture	1	$ 175,000
Total	94	$ 286,628,811
Source: HSB/ William Bartley- 2003 IMIA Conference		

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A Major “Driver” of Failures is the <u>Age</u> of Transformers 1

- Majority of transformers realistically have a design life of 25 to 30 years
- Age weakens both the mechanical and Dielectric-withstand strength of a Transformer
- The Insulation in the Transformer tends to degrade over time making the unit more sensitive to voltage fluctuations

A Major "Driver" of Failures is the Age of Transformers 2

"Insulation Degradation" is often a function of 4 variables that can cumulatively add up to a loss:

- Oil Contamination
- Heat
- Voltage surges /over voltage (lightening etc)
- Mechanical "thru-fault"/ over current hits (groundings etc)

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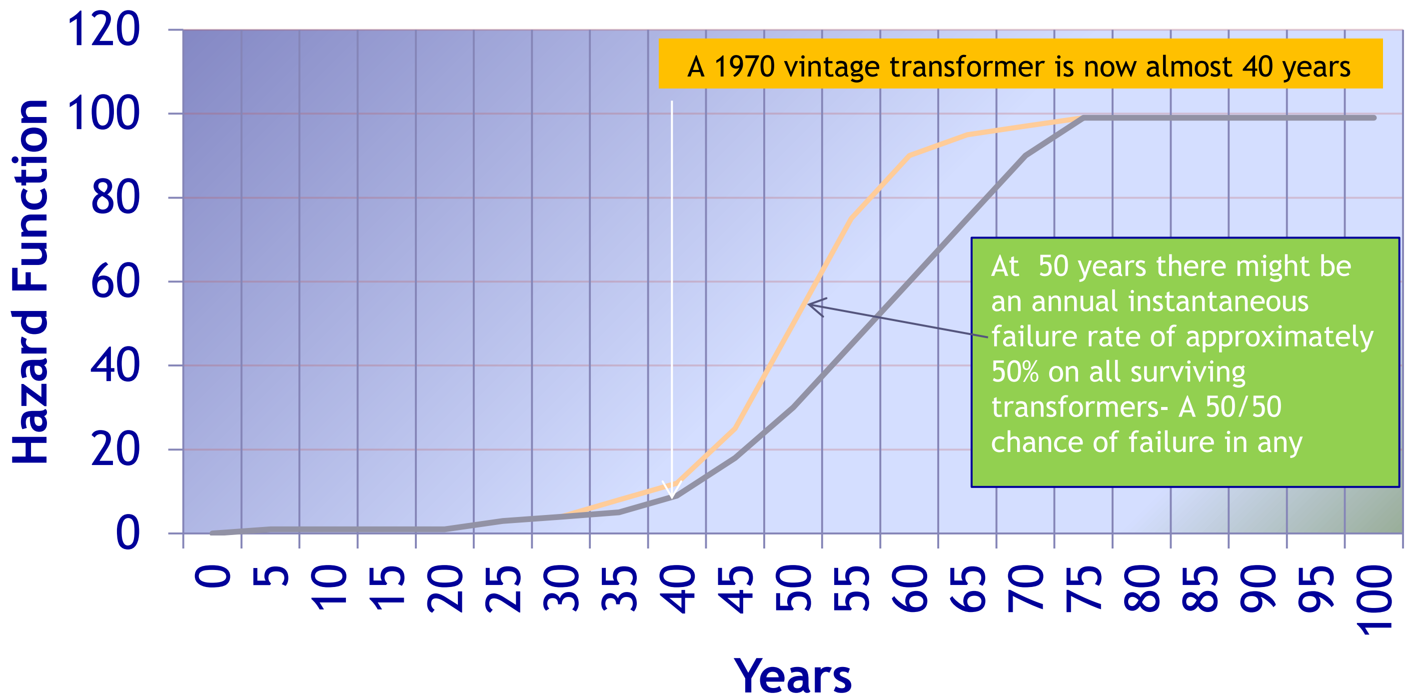
Transformer Failure Rate Function



Source: Red Curve -HSB/ Bill Bartley 2003 IMIA Conference; Blue Curve- A hypothetical alternative curve.

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Distribution of Losses by Age of Transformer

Age at Failure	# of Failures	Cost of Failures
0 to 5 Years	9	$ 11,246,360
6 to 10 years	6	$ 22,465,881
11 to 15 years	9	$ 3,179,291
16 to 20 years	9	$ 10,518,283
21 to 25 years	10	$ 16,441,930
Over 25 Years	16	$ 15,042,761
Age unknown	35	$ 207,734,306

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The Existence of Blast Walls and Fire Suppression Systems Often Does Not Stop a Total Loss From Happening

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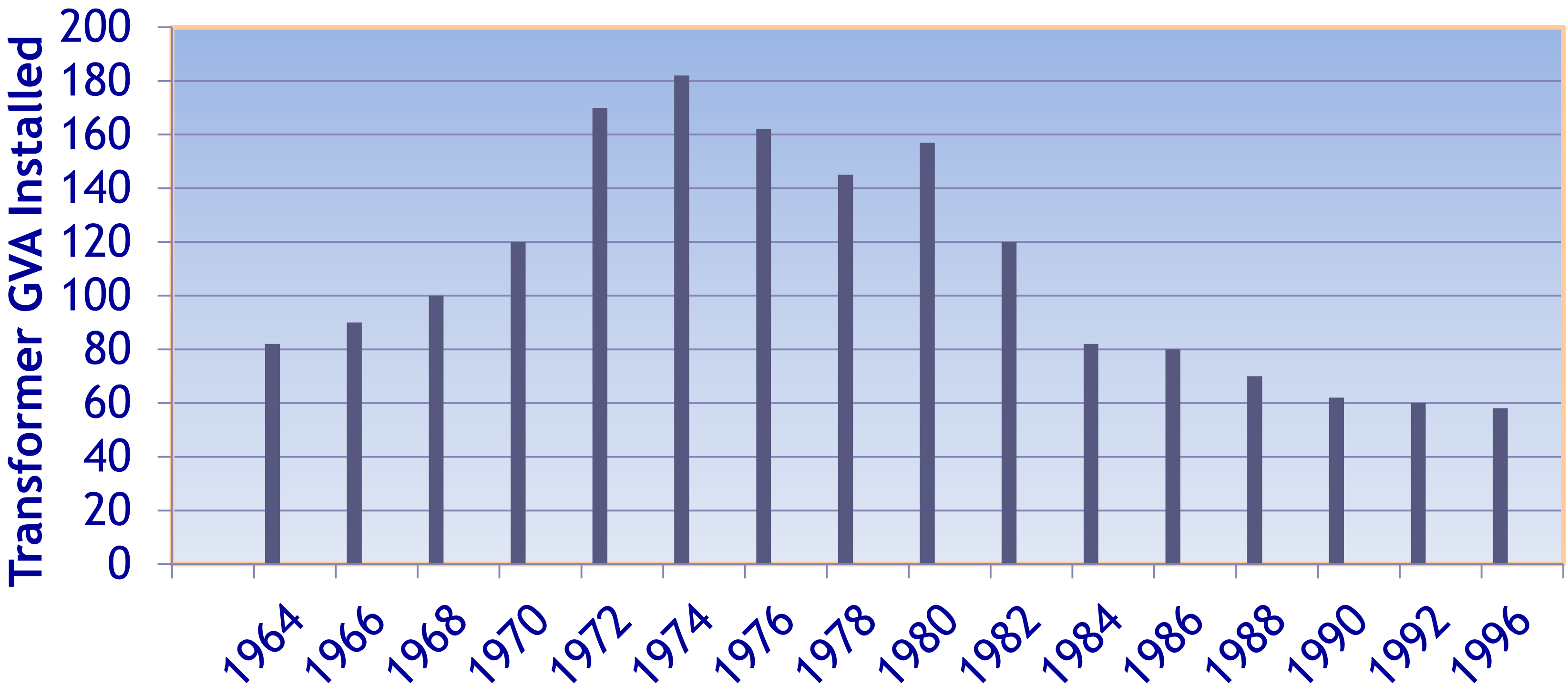
New Transformer Installations by Year (U.S. Commerce Data)



Source: HSB Bill Bartley 2003 IMIA Conference

Installation Data STRONGLY Suggests that Transformer Losses Will INCREASE in the Future!

- Units installed in 1970s are now almost 40 years old - *Equipment is reaching end of its design life*
- Cost considerations have often weakened replacement cycles and maintenance
- General trend shows demand to be increasing- *Demand + Old Insulation = Failures*

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An Important Observation

- While GSU Transformer Failures are a “hot” topic - we should not forget that the real issue is any situation where a GSU Transformer is not working when it is supposed to be working

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Press Capturing Photographs Like This Tend to Make Us Focus Only on Failure Situations that are Associated with a Fire Vs. Other Situations That Might Require a GSU Transformer Being Out of Commission for an Extended Period of Time

The Cause of a Transformer Failure Might be Due to Another Piece of Equipment Failing

Or Transportation - Transformers Tend to Have High Centers of Gravity

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Transformers Also Tend to Not Float

A More Common Sight in the U.S.

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GSU Transformers are a Global Business #1

- Even though a transformer is used by a utility here in the U.S., the logistics are global and often require a variety of transportation types
- In the Spring of 2010, a large global utility installed a new transformer in Indiana costing $2.5 million and weighing 216 tons (432,541 lbs)
- This transformer was built in South Korea, transported by ship to New York City; sent by rail from NYC to West Terre Haute, Indiana; and then transported by road (fyi- the transformer’s trailer broke-down a few miles from the substation)

GSU Transformers are a Global Business #2

- In 2011, a large utility was due to receive a transformer that was built by a leading OEM
- Due to an opening, the OEM provided attractive terms if the transformer could be built in Bogota, Columbia
- Heavier than expected seasonal rain weakened roads and bridges to the Port of Cartagena making the transport of the transformer not allowed by government officials

GSU Transformers are a Global Business #3

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Loss Control Observations #1

- A GSU Transformer that does not work for any reason can mean significant social and economic losses
- It should be recognized that a GSU Transformer's inability to work when scheduled might be due to several causes:
  - Delay in delivery
  - Transformer itself
  - Transportation/ Installation
  - Weakness in another part of the high voltage "system"
  - Operator error
- Moreover, it is not uncommon that incorrect/improper equipment was installed in the first place so an understanding of the "system" is essential

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Loss Control Observations #2

- There needs to be careful consideration of not only transportation issues but also installation issues weight/ dimensions/ cooling aspects etc. when looking for a replacement GSU transformer - Not all transformers that share the same specs have the same size and weight and often times the job site has been “customized” to house the existing equipment
- A firm’s advertised inventory of replacement transformers, their condition, and related service capabilities might not be credible or, importantly, client focused

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Loss Control Observations #3

- Moreover, knowing who has the necessary equipment available to perform the job is important (vacuum rigs, oil, testing equipment, related tools and equipment)
- Knowing what firms and, more importantly, *what people* at a given firm have demonstrated experience in your situation is essential
- More directly, just because someone represents that they have many years of "industry experience", it does not mean that they have many years of fast-track transformer experience that can lead to an appropriate solution being delivered efficiently (or safely)

Loss Control Observations #4

- Likewise, there is often essential to have the expertise necessary to work with a client and its partners to help clarify both “tactical” and “strategic” objectives (these two objectives can be very different and both these objectives often should be explored/ revisited when exploring any “fast-track” solution)

Loss Control Observations #5

- Lastly, the best solution frequently requires a unique “MacGyver Solution” to be delivered on a Fast-Track basis
  - Modify OEM equipment quickly to fit unique site configurations/requirements
  - Modify surrounding equipment to accommodate the identified Transformer and Build new equipment
  - Combine 2 or more Transformers in parallel

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Size And Shape of Transformers are Variable- the Same MVA Does Not Equal the Same Size

Two GSU Transformers Connected in Parallel

Size and Shape of Transformers are Variable - Locations Often are Not- Example of a Tight-fit Installation Using Wire Vs. Buss

Can the Process of Addressing a GSU Transformer Failure be Improved? - Internal Considerations

- Is there a real-world transformer or related equipment failure plan in place?:
  1. Who at the client can make the decision on what equipment alternative(s) to select: new/ used equipment; temporary or permanent equipment; what specific equipment is best suited to “strategically" replace the failed equipment?
  2. What specific information is required to make a decision?
  3. Who has (or can quickly get) the necessary information?
  4. Where will the funding to buy this equipment come from?
  5. Who will be responsible of communicating situation to insurance carrier and transmitting related guidance to the appropriate parties?

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Can the Process of Addressing a GSU Transformer Failure be Improved? - Selection of a Solution Provider

- Who are the people who are doing the work and what is their experience as individuals and as a team on similar "Fast-Track" assignments?
- Does the team take precautions to mitigate problems with their work (one-piece work suits, empty pocket checks, equipment inventory checklists etc) in addition to taking personnel safety precautions.
- Does the firm have the necessary equipment to get the job done and have the necessary working relationships with others in the industry to get a job done or problem solved.
- Are there firm / viable contingency plans in place and related resources should something go wrong?...a piece of equipment that fails; need for additional oil; specialized tools etc

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Can the Process of Addressing a GSU Transformer Failure be Improved? - The Cost of a Failure

- Importantly, is there common agreement between all parties including management, operations, financing sources, and insurance carriers (and the increasing possibility of outside agencies) as to both the social and hard dollar economic consequences of a failure and what likely courses of action will be taken if a failure happens?

Monthly Average Price of Electricity

Average Weighted Hourly Price (¢/kWh)													
Year	Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	3.15	3.30	3.37	3.16	2.97	2.59	3.46	3.71	3.45	3.12	2.85	2.88	2.58
2010	3.79	3.83	3.64	2.88	3.17	4.04	4.16	5.43	4.68	3.43	3.02	3.25	3.48
2009	3.16	5.48	4.86	3.06	1.96	2.91	2.48	2.01	2.84	2.21	3.03	2.76	3.60
2008	5.17	4.25	5.44	5.82	5.14	3.65	6.23	6.23	5.00	5.23	4.71	5.36	4.83
2007	5.05	4.62	6.08	5.69	4.80	4.11	4.80	4.72	5.73	4.76	5.12	4.85	5.18
2006	4.88	5.71	4.90	5.01	4.54	4.96	4.82	5.43	5.67	3.68	4.17	5.14	4.17
2005	7.21	5.98	5.05	6.10	6.36	5.47	7.12	8.20	9.52	9.97	8.02	6.07	8.39
2004	5.22	6.95	5.43	5.02	4.73	5.05	4.94	4.78	4.55	5.13	5.04	5.38	5.28
2003	5.76	6.23	8.86	8.48	6.16	4.51	4.53	4.27	5.15	5.05	5.90	4.19	4.68
2002	5.59	-	-	-	-	3.00	3.71	6.20	6.94	8.31	5.09	5.12	5.93

Average Hourly Prices for each month since market opening on May 1, 2002.

Averages are weighted by the amount of electricity used throughout the province within each hour.
Source: http://www.ieso.ca/imoweb/siteshared/monthly_prices.asp

"Lost Profit per kw/Hour"

- The selection of a "lost profit per kw/hour" number to use in any business interruption calculation is not as easy as one might first imagine. One needs to know what the average sales price per kw/hour is during the period of the failure and the average cost to produce the power per kw/hr during this same time frame
- The difference between these amounts is a simple way of calculating the "lost profit per kw/hour" (lost business income per kw/ hour) due to the failure
- It should be highlighted that even a small change in the "lost profit per kw/hour" number (in cents or fractions thereof) used in a failure situation can make a huge difference in the ultimate calculation in "lost profits" when expressed in total dollars

Observations on the High Cost of Business Interruption / Business Income Losses

- GSU failure history indicates that many transformer failures happen at high demand/ price times when loads on GSU transformers are greatest. More often or not the related exposure information is dated (PPA agreements, take or pay agreements; operational profit/ loss assumptions etc)
- There will likely always be strong debate on the appropriate numbers to use when calculating the cost of producing/sourcing power (example: only allowing certain variable costs vs. all variable and fixed costs etc) in any failure situation
- A significant amount of stress (and litigation costs) can be avoided by having all parties to a failure (insured, insurance company, accounting parties etc) sharing agreed/ clear understandings in advance

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Back of the Envelope Assumptions/ Calculations on Cost of a Failure

- Transformer MVA to MW Formula: GSU Transformer' highest MVA Rating ("size") X Power Factor (usually a figure between .80 to .98 with .85 a common rule of thumb) = MW of generation capacity by the power generating entity
- Example: a 100 MVA transformer supports the generation of 85 MW of power per hour by a turbine/ generator combination assuming a Power Factor of .85. By this math, the failure of a 100 MVA transformer means that 85 MW of power cannot be sold per hour
- The $.01 "lost profit per kw/ hour" used in the following table has no basis other than to illustrate a situation where the power producer might have been selling power at $.05 and with a $.04 cost of power production (however defined). $.05 -.04= $.01 etc.

Basic Calculations: The High Cost of GSU Transformer Failures

Transformer @ Largest MVA Rating	Generation @ MW/hr (.85 PF)	Generation @ kw /hr	Price @ $ .01 per kw /hour	Price @ 24 hour day	Price @ 7 day week	Price @ 30 day month
50	43	42,500	$ 425	$ 10,200	$ 71,400	$ 306,000
100	85	85,000	$ 850	$ 20,400	$ 142,800	$ 612,000
150	128	127,500	$ 1,275	$ 30,600	$ 214,200	$ 918,000
200	170	170,000	$ 1,700	$ 40,800	$ 285,600	$ 1,224,000
250	213	212,500	$ 2,125	$ 51,000	$ 357,000	$ 1,530,000
300	255	255,000	$ 2,550	$ 61,200	$ 428,400	$ 1,836,000
350	298	297,500	$ 2,975	$ 71,400	$ 499,800	$ 2,142,000
400	340	340,000	$ 3,400	$ 81,600	$ 571,200	$ 2,448,000
450	383	382,500	$ 3,825	$ 91,800	$ 642,600	$ 2,754,000
500	425	425,000	$ 4,250	$102,000	$ 714,000	$ 3,060,000

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Final Observations #1

- How much will it cost in economic terms for each day of your power generation operation not being able to transmit power?
- What loss control plans and training can a client put into place to lower the cost of its insurance and/or improve the insurance coverage it receives?
- What internal and external incentives are there for a client to put into place a pro-active loss control plan that involves both management and operations levels?

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Final Observations #2

- What incentives are there for a client to respond quickly to a transformer failure? What penalties exist if a client does not respond to a transformer failure quickly? How is the term “quickly” defined?
- If an insurance company is bearing the majority of economic costs of a transformer loss, why does it often take so long before the insurance company can offer its ideas for a solution?

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Final Observations #3

- Are there ways for a client and an insurance company to pre-agree on ways to most efficiently address a possible loss situation thus reducing the economic and social costs to all parties?
  - Common understanding on the likely amount of business interruption / business income losses at certain times of the year
  - Common agreement on how business interruption / business income losses should be calculated
  - Common agreement on what Equipment would be selected as a replacement should a given GSU Transformer fail

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Final Observations #4

- Demand for power in the U.S. is expected to increase in the future putting more pressure on existing power production (and increasing the economic and social costs of an equipment failure)
- Regulatory agencies have become increasingly “interested” in making sure that power generation businesses are operated effectively to serve populations. It is likely that these regulatory agencies will become increasingly involved in loss control issues at the power plant level

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Final Observations #5

- Penalties for outages will likely increase especially when remedial actions could have been taken

  Tribune 10/25/12: "Governor Flogs PHCN Manager for Failing To Supply Electricity To His Community"

  "…..When the official could not give a satisfactory answer, the governor became annoyed and he flogged the PHCN official with a stick he was holding…. Mohammed Adamu said the affected member of staff was summoned and was beaten to a pulp by the governor and some of his aides….. as a result of a failed 2.5 MVA Transformer…"

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What Fast-Track Power Does #1

- We mitigate financial losses associated with power generation failures:
  - Restoring operations on a "fast-track" basis by quickly sourcing power equipment (for rent or sale)
  - Bringing a global network with the range of experience needed to address specific failure situations
- We provide open ("best of breed") architecture resources to all those involved in a failure, and we deliver these resources in a seamless / tune-key manner

What Fast-Track Power Does #2

- We do this with the largest known *global* expertise and resource base in the industry that spans over 7,000 people at premier firms.
  - Insurance/ reinsurance companies
  - Insurance brokers
  - Loss adjusters
  - Specialized accounting firms
  - Consulting engineers and large engineering firms
  - Staff at power generation facilities
  - GSU transformer OEMs
  - Secondary market sellers of new and used power-gen equipment
  - Specialized us and global transportation providers

What Fast-Track Power Does #3

- This contact base helps to lower the cost of equipment/ services costs and related business interruption costs by:
  a) Making equipment providers sharpen their pencils and speed up their work
  b) Providing alternative replacement options for consideration
  c) Reducing the risk of a failure in the replacement process
  d) Enabling other cost saving options to be explored
  e) Facilitating enhanced financing and insurance options

A Real- World Example of a Fast-Track Power Solution

GSU	Kva	Kva	Recommended by Consultant	Lead Time		Recommended by Fast-Track Power	Lead Time
80 MVA	138	13.8	$ 1,450,000	40-52 weeks		$ 900,000	2 weeks
80 MVA	138	13.8	Share with above			Share with above	
80 MVA	69	13.8	$ 1,350,000	40-52 weeks		Share with above	
90 MVA	138	13.8	$ 1,570,000	40-52 weeks		Share with above	
65 MVA (auto)	138	13.8	$ 1,100,000	40-52 weeks		$ 1,000,000	TBD *
6 MVA	13.8	4.16	$ 168,750	16-18 weeks		$ 85,000- $ 120,000	2 weeks
6 MVA	13.8	4.16	Share with above			Share with above	
6 MVA	13.8	4.16	Share with above			Share with above	
6 MVA	13.8	4.16	Share with above			Share with above	
Total Recommended Cost			**$ 5,638,750**			**> $ 2,000,000**	

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- We provide high-voltage equipment and services to solve immediate high-voltage transformer and related equipment needs on a global basis.
- Our worldwide contacts and industry specific knowledge base can help minimize the high cost of outages by offering competition and critical value-adding insight.
- Please consider us as an option when there is an immediate need.