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Description of document:	Idaho Public Utilities Commission (PUC) records concerning the risks to the electric power grid from geomagnetic storms, 2014-2015
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Source of document:	Idaho Public Utilities Commission Public Records Request P.O. Box 83720 Boise, ID 83720-0074 472 W. Washington Boise, ID 83702 Fax: 208.334.3762

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From: Jean Jewell Date: Feb 5, 2016 11:47:24 AM Subject: Your Public Records Request to the Idaho PUC

The Idaho Public Utilities Commission (PUC) received your public records request on February 2, 2016, requesting any memos, studies or reports (internal Commission documents and/or contractor reports) concerning the risks to the electric power grid from geomagnetic storms. A search of our records located two documents related to your request.

As the PUC's records custodian, I am forwarding these documents to you as attachments to this email. There is no charge for providing these documents to you.

Jean Jewell Commission Secretary Idaho Public Utilities Commission



An Introduction to Geomagnetic Disturbances (GMDs)

Bruno Leonardi 9/8/14

Imagination at work.

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Outline

Session 1 – Solar Flares & GMDs

Session 2 – Geomagnetic Induced Current (GIC) in Bulk Power System

- Session 3 GIC Calculation
- Session 4 GIC Effects on Power System Equipment
- Session 5 The NERC GMD standards

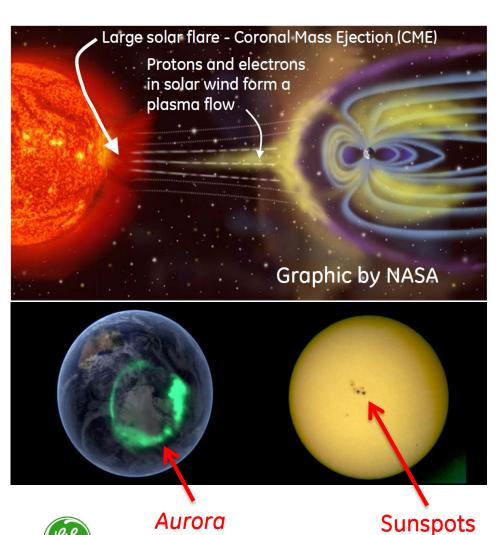
Session 6 – PSLF GMD Capabilities



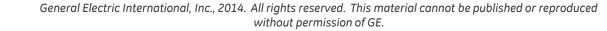
Solar Flares & GMDs



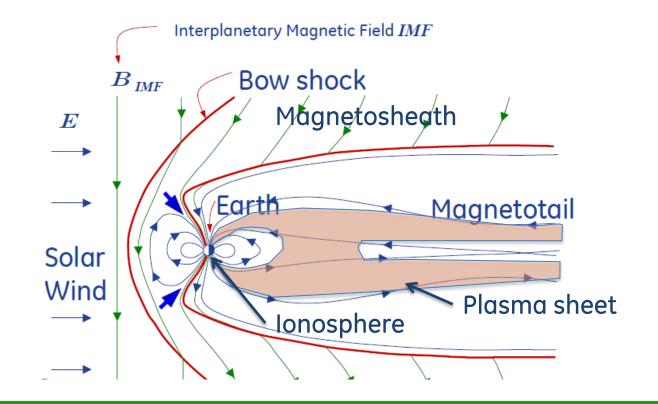
Solar Flare



- The Sun continuously emits solar particles through solar winds
- Occasionally, large masses of energized particles (electrons and solar wind ions) escape from Sun's corona and travels across space
- These masses of energized particles are called coronal mass ejections (CMEs)
- The interaction between these energized particles and earth's ionosphere causes GMDs



Charged Particles Travel through Space and Interact with Earth's Magnetic Field



The interaction of CMEs with earths magnetosphere-ionosphere produces ionospheric currents called **electrojets**



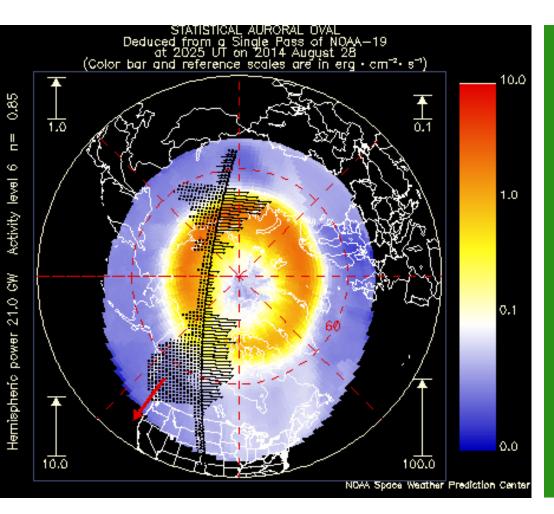
Injection of Highly Energized Particles in the Poles

https://www.youtube.com/watch?v=9Mv6xfeHY9E





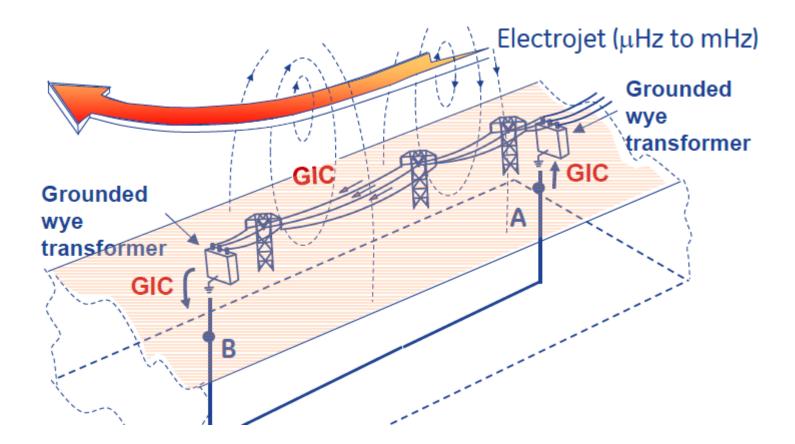
Aurora borealis and australis are also caused by solar winds



- In average intensity storms, the aurora oval is mostly contained to higher latitudes
- This is not true for stronger solar storms, which causes electrojets to flow over lower latitudes causing GICs in the power grid



Electrojets induce Electric Field Near Surface of the Earth



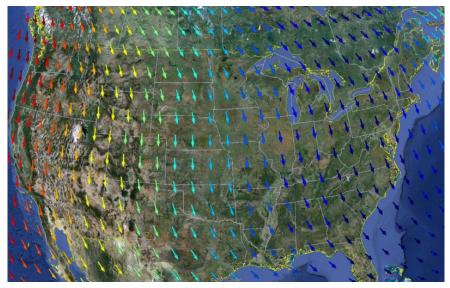


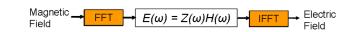
What is a Geomagnetic Disturbance (GMD)?

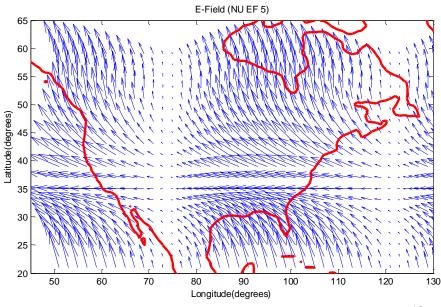
- A Geomagnetic Disturbance is a perturbation of earth's magnetic field density $\frac{\partial \vec{B}}{\partial t}$ due to energized solar particles
- This variation of the **magnetic field** produce an **electric field** near the earth's surface, which will then induce a DC voltage along the length of a transmission line in accordance to Faraday's Law



Non-Uniform, Time-Varying Electric Fields Will Induce DC Voltages on Transmission Lines



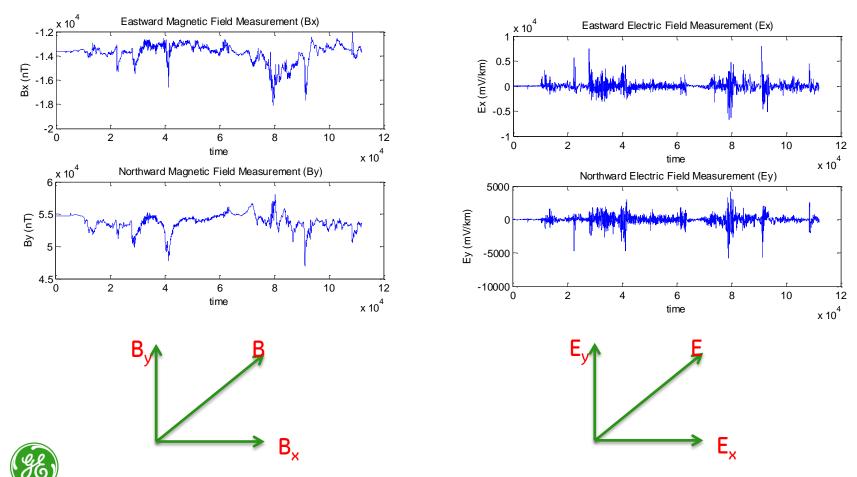






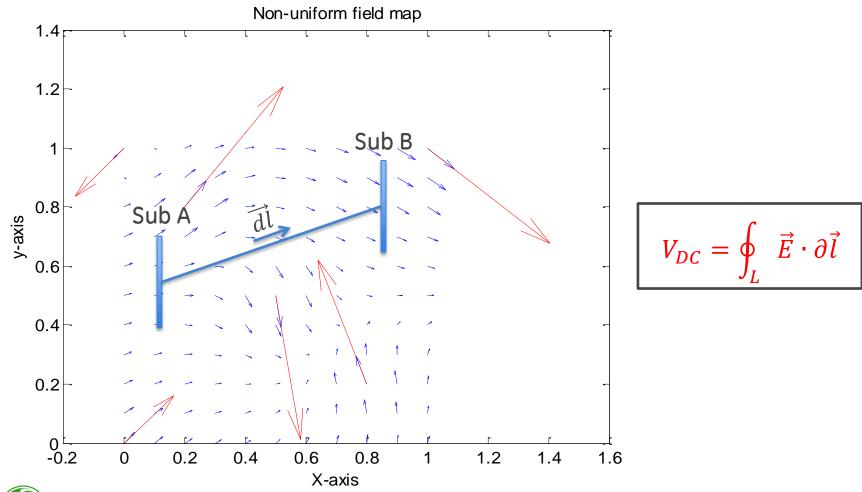
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Geomagnetic and Geoelectric fields in the 1989 solar storm (Ottawa observatory)



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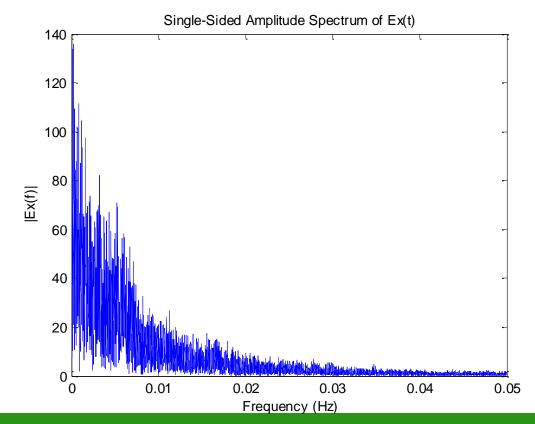
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V<sub>DC</sub> Calculation Via Faraday's Law
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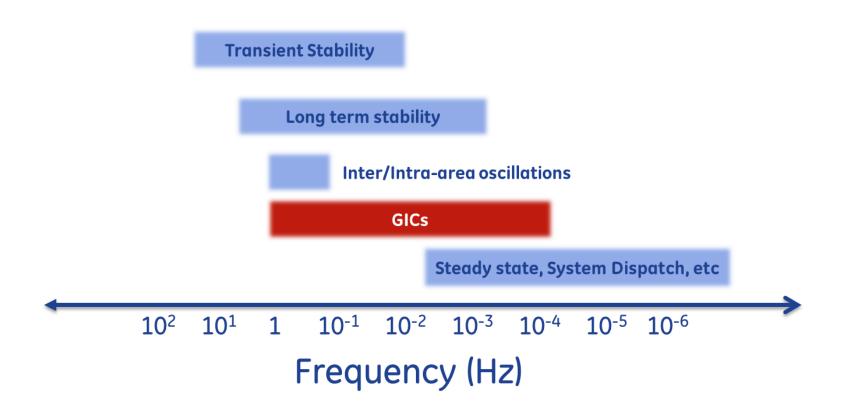
Spectral Composition of 1989 Storm Electric Field Sample



Traditionally, GICs frequencies are assumed to vary between **0.0001Hz and 1Hz**, with lower frequency components being predominant

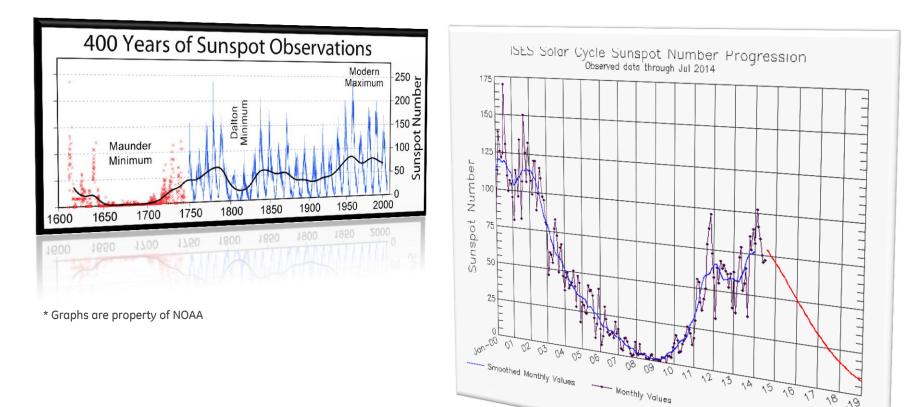


GMD phenomena time scale





Solar cycle has a period of approximately 11 years



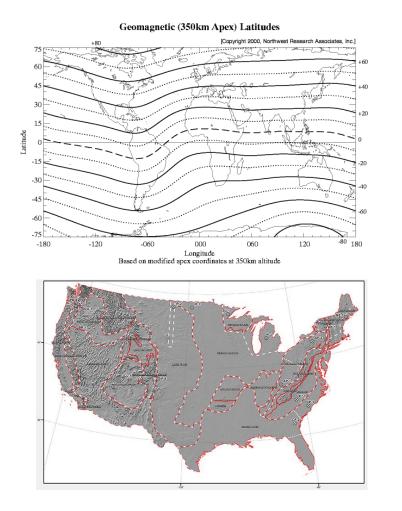


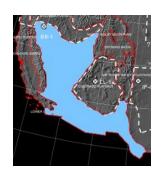
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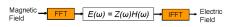
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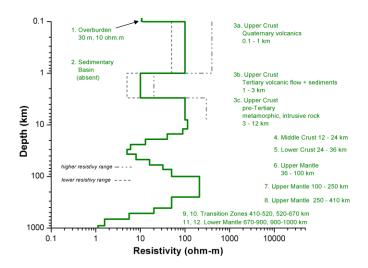
- Predicted Values (Smoothe

GIC intensity depends on the geomagnetic latitude and soil conductivity profile





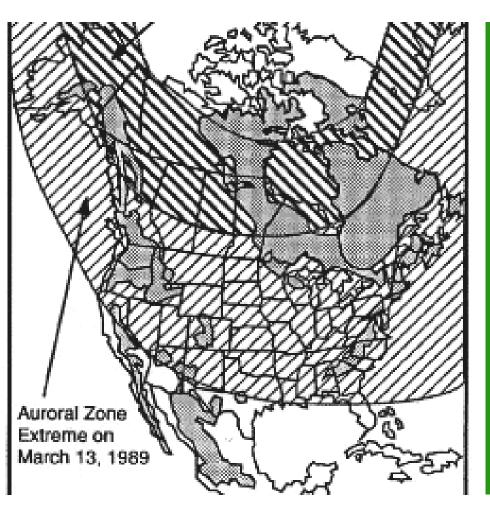






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Auroral Zones and Igneous Rock Regions



- Areas of igneous rock (show in gray) prone to higher GICs
- This happens because the induced electric field is higher is areas of low soil conductivity
- Coastal areas can also be under higher E-field intensities due high conductivity seawater bodies



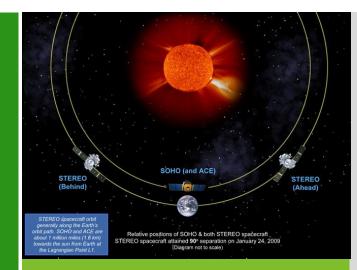
GMD Phenomena – from Sun to PSLF simulator

Science component		Power systems engineering component				
Solar flare	Earth magnetic field variation	Soil conductivity model	Induced E-field and voltage near earth's surface	DC voltage and GIC calculation	Additional VAR demand due to transformer saturation	Power systems steady state and dynamic analysis
		e Normality Norm	$\vec{E}(t,s)$	$Y_{bus} \cdot V = I$	Q = f(GIC)	



Space weather monitoring

- Forecasters can determine if CME is earth directed
- Warnings regarding solar storms can be issues 14 to 96 hours before the effects are felt on earth
- Indices are used to determine intensity of solar storm (A index and K index)



* NASA Goddard Space Flight Center: http://stereo.gsfc.nasa.gov/img/sciencevis uals/preview/ST_orbit1.jpg

A number of satellites are used to provide space weather information, including the Solar Terrestrial Relations Observatory (STEREO) and the Advanced Composition Explorer (ACE) satellite.



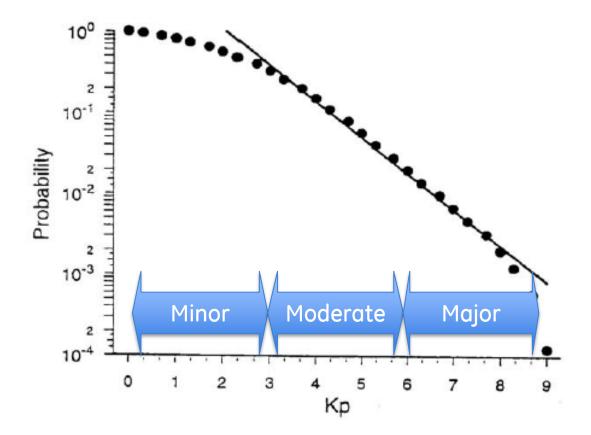
Storm levels and indices

Solar Activity	A index Level	K Index Level
Quiet	A < 7	1 < K <u><</u> 2
Unsettled	7 < A < 15	2 < K <u><</u> 3
Active	15 < A < 30	3 < K <u><</u> 4
Minor Geomagnetic Storm	30 < A < 50	4 < K <u><</u> 5
Major Geomagnetic Storm	50 < A < 100	5 < K <u><</u> 6
Severe Geomagnetic Storm	A > 100	K <u>></u> 7

Kp Index	NOAA Space Weather Scale Geomagnetic Storm Levels
Kp = 5	G1 (minor)
Kp = 6	G2 (moderate)
Kp = 7	G3 (strong)
Kp = 8	G4 (severe)
Kp = 9	G5 (extreme)



Storm Intensity Distribution (data measured from 1932-1991)





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NOAA Space Weather Notification Process

Identification	Notification	Mitigation
CME on the sun Magnetic deviation detected by ACE	NOAA and STDN Issue warnings East – MISO West – WECC Balancing authorities notified NERC and TOP Functions Notified	Real time System Operations Actions Taken



Geomagnetic Induced Current (GIC) in Bulk Power System



Tools for GMD study

- Given the low frequency of GICs, most of its effects on the bulk power system can be studied primarily with power flow tools
- Transient stability tools can be used to simulate the faster variations of a GMD disturbance
- Ideally, a long term quasi steady state tool would be ideal to simulate long, slow varying GMD disturbances
- Quasi steady state tools are not readily available commercially so a simplified time series power flow can be used instead (under certain assumptions)



Known GMD effects on power system equipment

- Transformer thermal damage
- Harmonic-induced equipment trip (SVCs, capacitors, etc.)
- Increased Var consumption due to transformer saturation
- Low voltages
- Generator heating (negative sequence currents)
- Protection misoperation due to CT saturation, others





Transformer at the Salem Nuclear Plant, damaged by March 1989 solar storm



Reported transformer effects to the 1989 storm

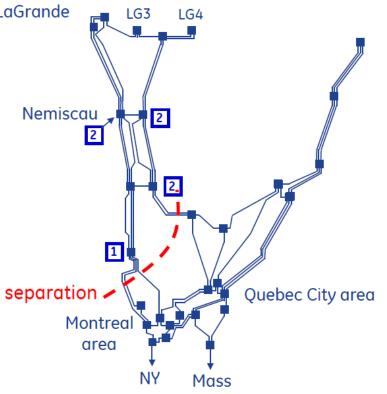
1. Salem Nuclear Plant (GSU #1)

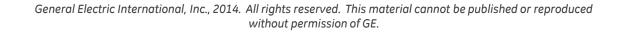
- i. Increased MVAr consumption (14% of nameplate rating)
- ii. Increase in combustible gases in oil (heating effect)
- iii. High noises
- iv. Degree of burning varied for different series connections
- 2. Salem Nuclear Plant (GSU #2)
 - i. Caused minor damage to one phase of transformer
- 3. Allegheny Power Systems (APS) (3-phase, 7-leg core shell form autotransformer rated 210/280/350 MVA)
 - i. Significant increase in dissolved combustible gases
 - ii. Discolored tank paint in four locations
 - iii. 14% increase in MVAr demand
 - iv. Increase in noise (10-15 dB)
 - v. Increase in harmonic current (THDi = 9.2%)
- 4. Other GMD related transformer reports in ESKROM (South Africa), National Grid (UK) and Transpower (New Zealand)



Hydro-Quebec Blackout

- HQ system was designed to operate ^{LaGrande} reliability and heavily depended on 7 SVCs and shunt reactors for voltage control
- Harmonic currents injected by GIC saturated transformers cause SVC protection to trip (sensitivity to harmonics)
- Trip of SVC lead to system instability separation
 and blackout of 83% of the load in Quebec
 Montre area
- It took nearly a 100s before the system was disrupted - HQ system restored in 9h ~150MW load loss in NY/~1400MW NE

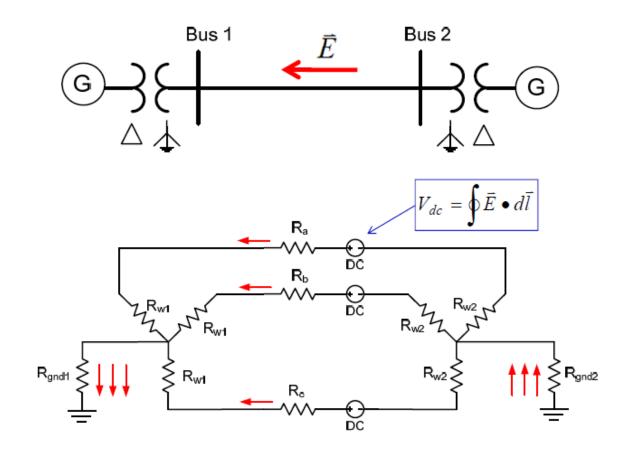




GIC calculation



Induced DC voltages drive GIC flow



*Picture from NERC report "Effects of Geomagnetic Disturbances on the Bulk Power Systems", February 2012.



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Data required

- E-Field data
- Substation data
- Transmission line data
- Transformer data
- Shunt data (reactors)

Table A8-2: Transmission line information

Line	From Bus	To Bus	Length (km)	Resistance (Ohms/phase)
1	2	3	121.03	3.525
2	4	5	160.18	4.665

Table A8-1: Substation location and ground grid resistance

Name	Latitude	Longitude	Grounding Resistance (Ohms)
Sub 1	33.613499	-87.373673	0.2
Sub 2	34.310437	-86.365765	0.2
Sub 3	33.955058	-84.679354	0.2

Table A8-3: Transformer and autotransformer winding resistance values

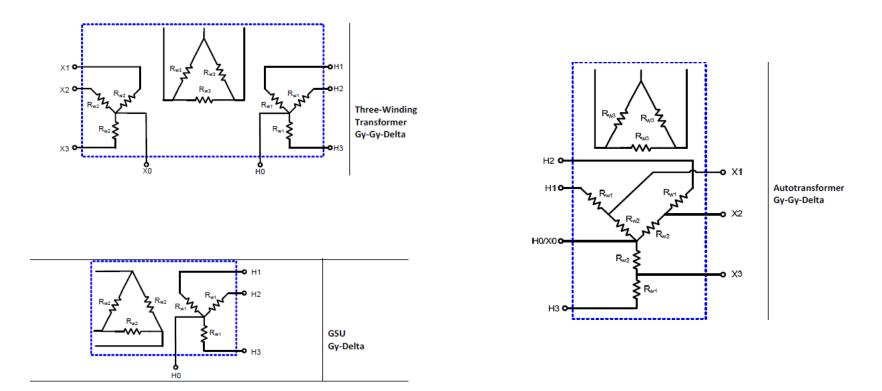
Name	Resistance W1 (ohm/phase)	Resistance W2 (ohm/phase)
T1	0.5	N/A
T2	0.2 (series)	0.2 (common)
T3	0.5	N/A

Table A8-4: Eastward and northward distance calculation results

Line	From Bus	To Bus	Northward Distance (km)	Eastward Distance (km)
1	2	3	-77.499	-92.96
2	4	5	39.518	-155.22

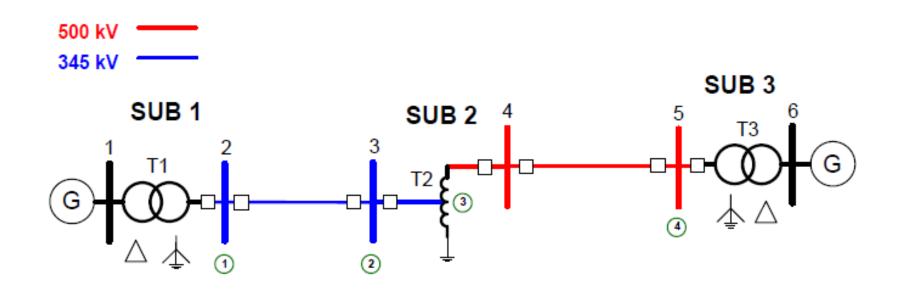


Transformer Winding Connections



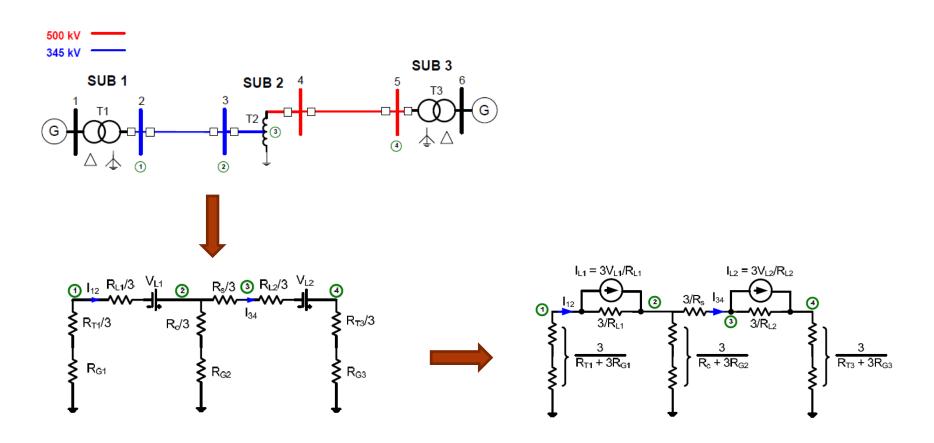


NERC 6 Bus Example





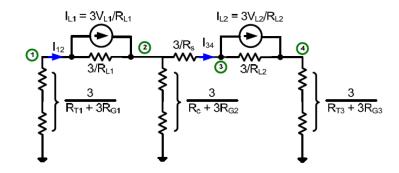
Equivalent DC network



***Example taken from NERC report "Effects of Geomagnetic Disturbances on the Bulk Power Systems", February 2012.



Nodal DC Voltage Calculation

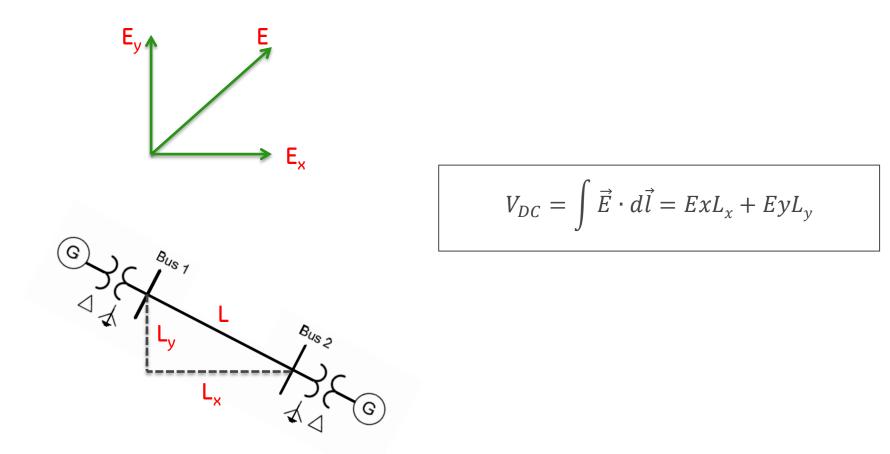


$$Y = \begin{bmatrix} \frac{3}{R_{T1} + 3R_{G1}} + \frac{3}{R_{L1}} & -\frac{3}{R_{L1}} & 0 & 0 \\ -\frac{3}{R_{L1}} & \frac{3}{R_{S}} + \frac{3}{R_{L1}} + \frac{3}{R_{C} + 3R_{G2}} & -\frac{3}{R_{S}} & 0 \\ 0 & -\frac{3}{R_{S}} & \frac{3}{R_{S}} + \frac{3}{R_{L2}} & -\frac{3}{R_{L2}} \\ 0 & 0 & -\frac{3}{R_{L2}} & \frac{3}{R_{L2}} + \frac{3}{R_{T2} + 3R_{G2}} \end{bmatrix} I = \begin{bmatrix} -I_{L1} \\ I_{L1} \\ -I_{L2} \\ I_{L2} \end{bmatrix} I = YV_{DC}$$



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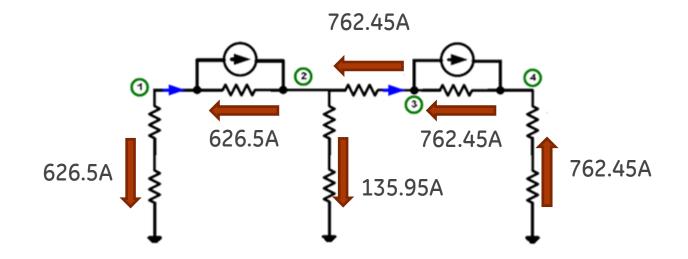
Calculation of Induced DC Voltage





GIC Calculation

• After the DC voltages in the entire network are known, it is trivial to calculate GICs in all equipment

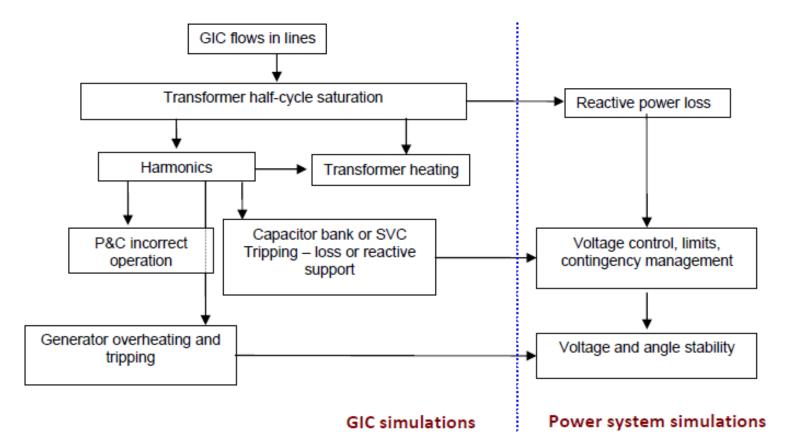




GIC Effects on Power System Equipment



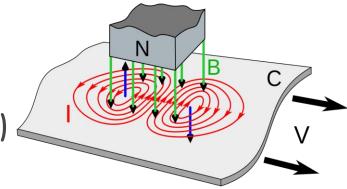
Overall Power System GIC impact





Transformer Impacts

- Increased amount of stray flux and consequently stray losses (thermal losses in structural parts)
- Core saturation places flux outside transformer core causing heating through eddy loss
- Localized heating in windings, tank walls and structural components

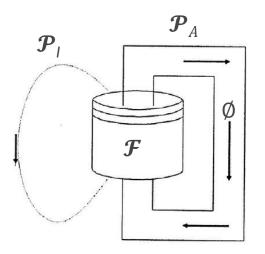


***"Eddy currents due to magnet" by Chetvorno -Own work. Licensed under Creative Commons Zero, Public Domain Dedication via Wikimedia Commons -

http://commons.wikimedia.org/wiki/File:Eddy_cur rents_due_to_magnet.svg#mediaviewer/File:Edd y_currents_due_to_magnet.svg



Basics of Transformer Magnetics



 \mathcal{F} – Magneto Motive Force (mmf) \emptyset – Magnetic Flux \mathcal{R} – Reluctance \mathcal{P} – Permeance N – # of Turns

$$\mathcal{F} = \emptyset \cdot \mathcal{R} = NI$$

$$I = \frac{\emptyset}{N(\mathcal{P}_A + \mathcal{P}_I)}$$

$$V = -N \frac{\partial \phi}{\partial t}$$

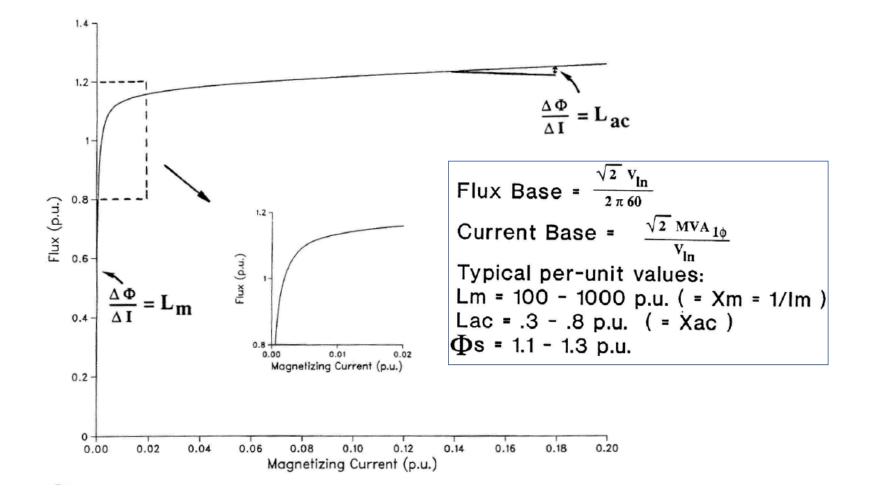
 $\phi = \frac{-1}{N} \int V \, dt$

$$I = -\frac{\int V \, dt}{N^2 (\boldsymbol{\mathcal{P}}_A + \boldsymbol{\mathcal{P}}_I)}$$



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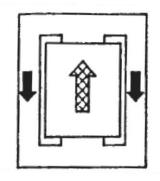
Typical Saturation Curve

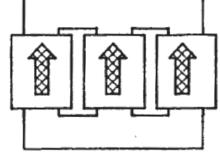




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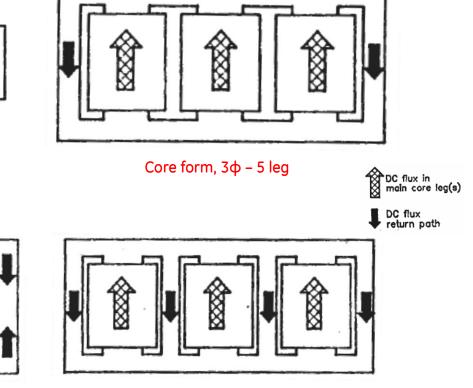
Transformer types





Core/shell form, 1ф

Core form, 3 ϕ – 3 leg

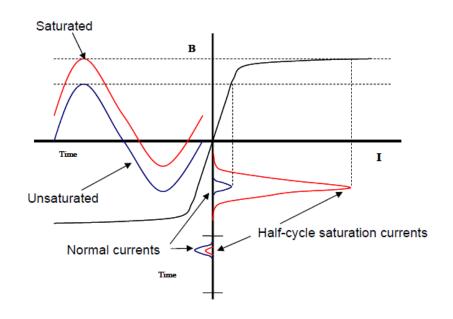


Shell form, 3φ

Core form, $3\phi - 7 \log$



Transformer Half-Cycle Saturation



- DC current creates an offset in the magnetizing current
- Only half cycle of magnetizing current enters saturated region
- Harmonic currents have both even and odd components and decay with harmonic order

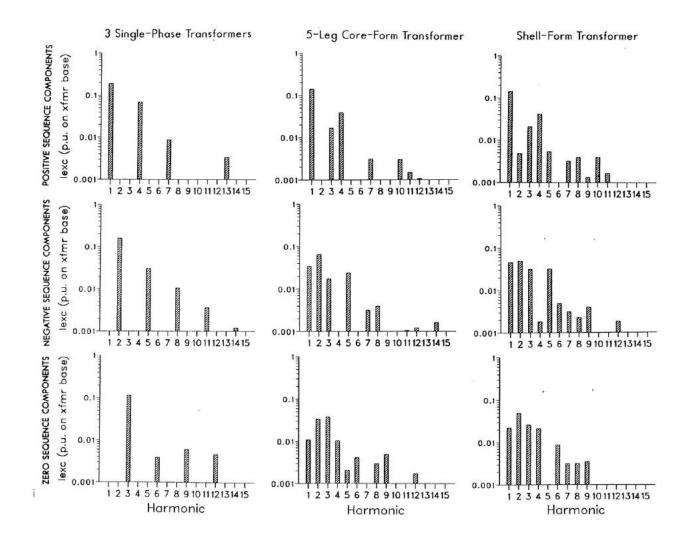


Harmonics Impacts

- Saturation distorts wave form and introduces harmonics into the system
- Causes equipment overheating due to Eddy losses
- Capacitor & SVC overload (remember, shunt capacitors are seen as low impedance paths for high frequency components)
- Control and protection misoperation mostly due to CT saturation (modern relays do not rely on CTs)
- Generator thermal stress due to negative sequence currents can cause generator heating and tripping



Symmetrical Components at 0.1 p.u GIC





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Potential events during a GMD event

Reduced stability margin

- Depressed voltages
- Reduced reactive reserves
- Transformer out of service
- Increased power transfers

Increased potential for abrupt disturbances

•

Protective tripping of transformers, capacitors, SVCs Protection system less reliable

- False trips
 - Delayed tripping, failure to trip for actual faults

Increased risk of operator error

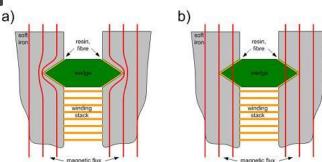
- Unusual symptoms
- Unfamiliar operating regime



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Generator Impacts

- Increased negative sequence harmonic currents resulting in increased generator heating
- Potential damage to rotor body/wedges due to heating can create a fatigue crack initiation site
- Increased mechanical vibration
- Potential to resonance near 6th harmonic (electrical and mechanical)
- Negative sequence relay operation or erratic behavior due to harmonics





Capacitor Bank Impacts

- Increased bank loading and RMS current due to harmonic components
- Ungrounded bank will see less RMS current because it blocks zero sequence component
- Potential resonance between cap bank and transformer air core reactance
- Failure of small portions of the bank (capacitor cans) and bank tripping due to unbalanced relay operation





NERC GMD Standards



Two Standards Were Developed

- FERC Order directs NERC to file standards that address GMDs.
- Standards are to be implemented in two stages
 - EOP-010-1 Geomagnetic Disturbance Operations
 Effective Mid 2014
 - TPL-007-1 Transmission System Planned Performance for Geomagnetic Disturbance Events – Effective Mid 2015



EOP-010-1 Requirements

Each Reliability Coordinator shall develop, maintain, and implement a GMD Operating Plan

Each RC shall disseminate forecasted weather information to functional entities identified as recipients in the Reliability Coordinator's GMD Operating Plan

- Activities designed to mitigate the effects of GMD events
- Steps or tasks to receive space weather information.
- System Operator actions to be initiated based on predetermined conditions.
- Conditions for terminating the Operating Procedure



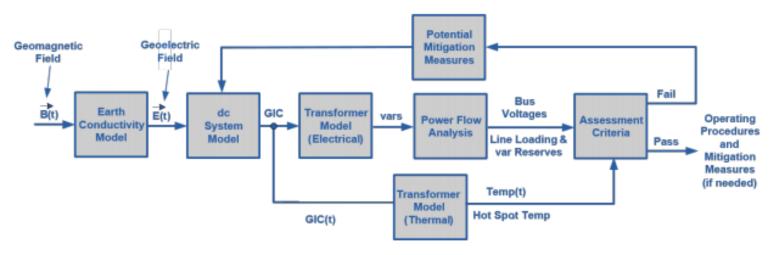
TPL-007-1 Requirements

Planning Coordinators and TPs must maintain models and perform studies needed to complete GMD Vulnerability	Shall develop a criteria for acceptable system steady state voltage performance for its System during the benchmark GMD event
PCs and TPs shall complete a GMD Vulnerability Assessment of the Near-Term Transmission Planning Horizon once every 60 calendar months	PCs and TPs shall provide GIC flow information to be used for the transformer thermal impact assessment to each Transmission Owner and Generator Owner



TPL-007-1 Requirements (continued)

Transmission Owner and Generator Owner shall conduct a thermal impact assessment for each transformer where the maximum effective GIC value is >= 15 A/per phase System does not meet the performance requirements of specified in the standard, a Corrective Action Plan shall be developed for adequacy





System Performance Requirements According to TPL-007-1

Table 1 – Steady State Planning Events

Steady State:

- a. Voltage collapse, Cascading and uncontrolled islanding shall not occur.
- b. Generation loss is acceptable as a consequence of the planning event.
- c. Planned System adjustments such as Transmission configuration changes and re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings.

Category	Initial Condition	Event	Interruption of Firm Transmission Service Allowed	Load Loss Allowed
GMD GMD Event with Outages	 System as may be postured in response to space weather information¹, and then GMD event² 	Reactive Power compensation devices and other Transmission Facilities removed as a result of Protection System operation or Misoperation due to harmonics during the GMD event	Yes ³	Yes ³

Table 1 – Steady State Performance Footnotes

- 1. The System condition for GMD planning may include adjustments to posture the System that are executable in response to space weather information.
- 2. The GMD conditions for the planning event are described in Attachment 1 (Benchmark GMD Event).
- Load loss as a result of manual or automatic Load shedding (e.g. UVLS) and/or curtailment of Firm Transmission Service may be used to meet BES performance requirements during studied GMD conditions. The likelihood and magnitude of Load loss or curtailment of Firm Transmission Service should be minimized.



All Requirements are Based on the Benchmark Storm

$\mathsf{E}=8{\cdot}\alpha{\cdot}\beta~(\mathsf{V}/\mathsf{km})$

- E = Electric Field
- α = Geomagnetic scaling factor
- β = Soil conductivity scaling factor

N	eld Scaling Factors	Table 2: Geomagnetic Fie
PE	Scaling Factor1	Geomagnetic Latitude
Pl	(α)	(Degrees)
P	0.10	≤ 40
S	0.2	45
SL	0.3	50
BC	0.5	54
FE		
PF	0.6	56
B	0.7	57
PRA	0.8	58
SHI	0.9	59
ATLA	1.0	≥ 60

USGS	ric Field Scaling Factors Scaling Factor
Earth model	(β)
AK1A	0.56
AK1A AK1B	0.56
AP1	0.33
AP2	0.82
BR1	0.22
CL1	0.76
C01	0.27
CP1	0.81
CP2	0.95
CP3	0.94
CS1	0.41
IP1	0.94
IP2	0.28
IP3	0.93
IP4	0.41
s NE1	0.81
PB1	0.62
PB2	0.46
PT1	1.17
SL1	0.53
SU1	0.93
BOU	0.28
FBK	0.56
PRU	0.21
BC	0.67
PRAIRIES	0.96
SHIELD	1.0
ATLANTIC	0.79



PSLF GMD Capabilities



PSLF Capabilities

- Major studies required by TPL-007-1
 - GIC calculation (PSLF)
 - Steady state analysis (PSLF)
 - Time series analysis (PSLF)
 - Transformer thermal impact analysis (GE Energy Consulting) – NERC has a guide for transformer thermal impact analysis



Data Required

	Addit	ional data	
GMD DISTURBANCE	SUBSTATION	TRANSMISSION LINES	TRANSFORMERS
GMD induced Electric Field	Ground mat resistance	Line DC resistance*	Transformer winding DC resistance*
	Bus/Substation Latitude/Longit ude		Transformer winding connection*
			K factor (saturation)
			Blocking device/ground
			Transformer type (auto, 3-leg core, shell, etc)



Four new tables have been created to store GMD data

- substation table
- secddg table
- trang table
- e-field table (for non-uniform e-field)



Substg table

🕠 Tabl	e substg	[Last: 2 , Max: 80000]	cases\ 🗖 🗖 💌					
<u>T</u> able <u>O</u> p	otions Help		CurRow: 0					
NUM	NAME	RGMAT						
1	SUB1	0.2000						
2	SUB2	0.2000						
3	SUB3	0.2000						
	2020	012000						
find	fill insert	delete scan recEd p	rint colTot sort origVal refresh done					



Secddg table

🕠 Table	secddg	[Last: 5 , Max: 12	0000]	cases\AF9B	US.sav					
<u>T</u> able <u>O</u> pt	ions Help									
FROM	FNAME	FKV	то	TNAME	TKV	CK	SE	ST	RDCSEC	GIC (A/PHASE)
4	BUS4	230.0	5	BUS5	230.0	1	1	1	5.2900	0.0000
4	BUS4	230.0	6	BUS6	230.0	1	1	1	8.9930	0.0000
5	BUS5	230.0	7	BUS7	230.0	1	1	1	16.9280	0.0000
6	BUS6	230.0	9	BUS9	230.0	1	1	1	20.6310	0.0000
7	BUS7	230.0	8	BUS8	230.0	1	1	1	0.4496	0.0000
8	BUS8	230.0	9	BUS9	230.0	1	1	1	6.2951	0.0000



Trang table

🚯 Tabl	e trang	[Last: 2 , Max: 4	0000]	cases\Al	9BUS.sav											
<u>T</u> able <u>O</u>	ptions Help			Cu:	rRow: 0											
FROM	FNAME	FKV	то	TNAME	TKV	CK	S TYPE	PW	T SWT	TWT	SUBN	AUTO	KFACT	RDCPW	RDCSW	RDCTW
1	BUS1	17	4	BUS4	230	1	1 core	d	дХ		1	0	1.2000	0.0000	0.1000	0.0000
2	BUS2	18	7	BUS7	230	1	1 core	d	дХ		2	0	1.2000	0.0000	0.1000	0.0000
3	BUS3	14	9	BUS9	230	1	1 core	d	дХ		3	0	1.2000	0.0000	0.1000	0.0000
•				111												4
fin	d				scan									I	refresh	done

<u>(able Opti</u>	ions Help					CurRow	: 0								
RDCTW	BDPWS	BDPT	BDPWR	BDSWS	BDST	BDSWR	BDTWS	BDTT	BDTWR	GIC-P	GIC-S	GIC-T	GIC-PN	GIC-SN	GIC-TN
.0000	0	0	0.0000	0	0	0.0000	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.0000	0	0	0.0000	0	0	0.0000	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
.0000	0	0	0.0000	0	0	0.0000	0	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000



Efield Table

					CurRow: 0
NUM	X-COMP	Y-COMP	LAT.	LONG.	
1	1.0000	0.0000	43.1054	-75.8786	
2	1.0000	0.0000	42.7408	-73.0337	
3	1.0000	0.0000	42.2476	-74.6834	
4	1.0000	0.0000	40.5742	-73.6592	
5	1.0000	0.0000	41.6074	-75.7256	
6	1.0000	0.0000	42.7161	-72.5768	
7	1.0000	0.0000	41.7136	-71.5407	
8	1.0000	0.0000	39.4888	-74.6359	
9	1.0000	0.0000	39.4900	-74.1086	
10	1.0000	0.0000	41.0913	-73.8443	
11	1.0000	0.0000	42.6477	-74.6928	
12	1.0000	0.0000	43.7780	-75.7065	
13	1.0000	0.0000	42.2254	-73.4415	
14	1.0000	0.0000	40.9284	-75.4669	
15	1.0000	0.0000	40.5779	-72.6251	
16	1.0000	0.0000	41.5779	-75.6251	
17	1.0000	0.0000	39.4848	-73.3771	
18	1.0000	0.0000	42.0447	-75.7406	
19	1.0000	0.0000	41.3184	-74.2514	
20	1.0000	0.0000	40.1296	-73.2073	
21	1.0000	0.0000	43.5374	-72.7169	



Estimate GMD data with egmd tool

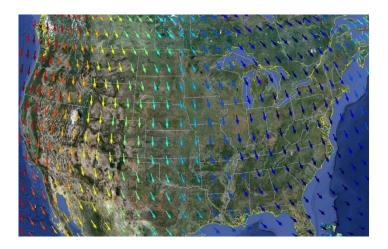
Starts from a power flow case and estimates the remaining GMD data

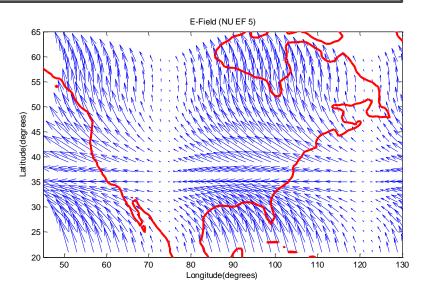
	ortCircuit Dynamics											
getf	savf	hgmd	Getting started		edit		dchk dsst					
rdyd	init	rgmd	Read GMD file		wdyd	<u> </u>	1220					
		wgmd	Write GMD file			- 60	0				6	~
Starting comp	iling [C:\upslf18	egmd	Estimate GMD data Calculate GIC	12:12 20	13	0	🖗 Open file					~~
unning PSLF JAVA	initialization f	cgic					Ontinun				-	
elease Date: Sep	tember 12 2012	gma_aits	Find Differences				Options					
erease pare: seb	CEREJEL 12, 2013	editg	Edit GMD data	•								
	International, In 0000 Bus Version	c.					Allow PS	LF to correct suspe	ct GMD dat	a No Sub da	ata available	-
-SEE - VI0.1_02 0	0000 bus version											
	is licensed for:											
ositive Sequence	Load Flow nent Short Circui						Enter .sub fil	<u>_</u>			0000	
	Dynamic Simulati						Enter .sub II	e			Open	
eo-Magnetic Dist	urbance Calculati	on										
texted up at .	un Oct 13 16:12:1	2 2012										
scarced up at: 5	un oct 15 16:12:1	2 2013					Use tran	sformer kfactor adju	istment op	tion		
							000000		aounone op	a on		
							Transfor	mer kfactor adjustm	nent base	500.00	(in kV)	
										OK	Correct	
										OK	Cance	



Simulates Uniform and Non-Uniform Electric Fields

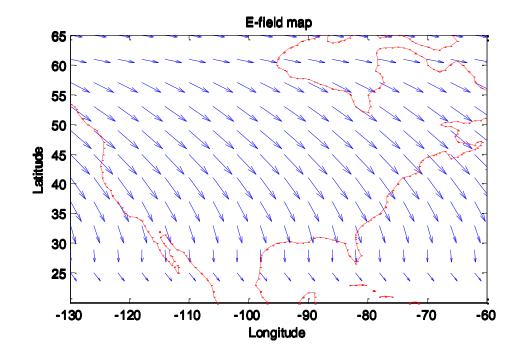
Enables users to model very complex E-field scenarios spanning over various latitudes and soil conductivity profiles





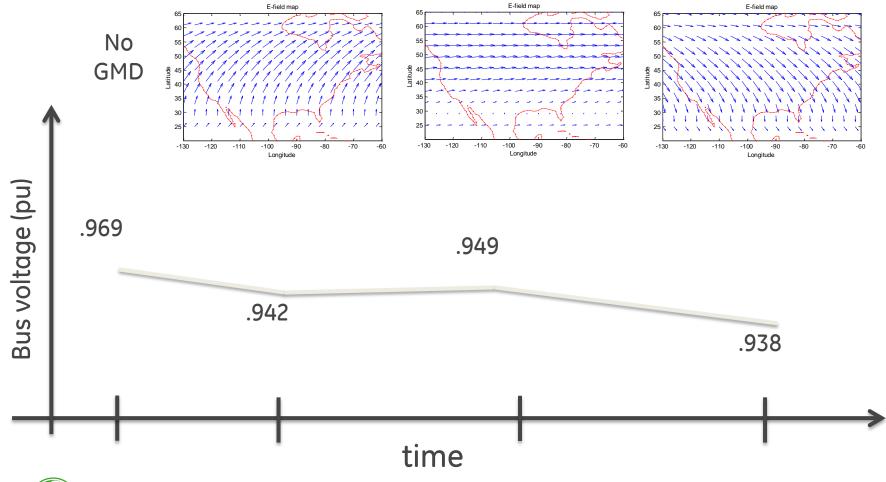


Non-uniform time varying E-field maps



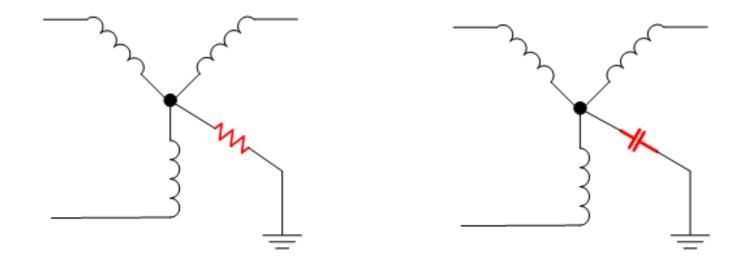


Time-series power flow analysis



(ge)

Transformer Neutral Blocking Devices



Allows modeling of resistive or capacitive blocking devices in transformer neutrals



GMD loads directly added to power flow case

IF Table load [Last: 41159 , Max: 60000] D:\Projects\GMD\AF9BUS	ast.sav		
able Options Help CurRow: 39862			
BUS-NO NAME KV ID ST PLOAD QLOAD IPLOD IQU	🙀 Record Disp Dialog	×	YI MI DI YO MO DO OWN LID
699942 LPC 69 69.00 1 1 0.00 0.00 0.00	Record load		40 01 1 39 12 31 0
699945 CGT 69 69.00 1 1 8.29 3.66 0.00 699946 CW7 GROENIER 69.00 1 1 2.43 -0.12 0.00	39862 126296 RAM PAR 345.00		40 01 1 39 12 31 0 40 01 1 39 12 31 0
699946 CW7 GROENIER 69.00 2 1 0.81 -0.15 0.00	39862 126296 RAM PAR 345.00		40 01 1 39 12 31 0
699952 LKHD DEL 4.16 1 1 3.47 1.68 0.00	Time stamp 190000 12	31/69	40 01 1 39 12 31 0
699954 ROOT RVR 7 24.90 1 1 27.41 9.01 0.00	· ·		40 01 1 39 12 31 0
699957 SWAN 24.90 1 1 45.77 15.08 0.00	* Bus no 126296 Ri	M PAR 345.00	40 01 1 39 12 31 0
699960 7THST_GB 138.00 1 1 18.77 4.50 0.00	* Load Id GO		40 01 1 39 12 31 0
699962 OEC 34.50 1 1 19.34 6.24 0.00	Project ID 0		40 01 1 39 12 31 0
699964 TAYLOR S 46.00 1 1 0.28 0.21 0.00 699970 PARKLAND 7 24.90 1 1 23.95 13.57 0.00			40 01 1 39 12 31 0 40 01 1 39 12 31 0
699971 FREDONIA 27.60 1 1 12.23 3.07 0.00	* Load Status 1		
699973 MOUNTAIN 13.80 1 1 1.32 0.78 0.00	Normal Status 0		40 01 1 39 12 31 0
699978 GLACIER 24.90 1 1 18.88 4.73 0.00	Area 102		40 01 1 39 12 31 0
699980 BROOKDL9 24.90 1 1 36.26 12.46 0.00			40 01 1 39 12 31 0
699981 RAYMOND 24.94 1 1 9.72 1.97 0.00	Zone 176		40 01 1 39 12 31 0
699983 CRIVITZ 138.00 1 1 5.05 1.67 0.00	* Const MVA P MW 0.000000		40 01 1 39 12 31 0
699995 AKR 69 69.00 1 1 2.21 0.33 0.00	* Const MVA O MVAR 0.000000		40 01 1 39 12 31 0 40 01 1 39 12 31 0
699995 AKR 69 69.00 2 1 7.85 1.18 0.00 699996 RPK 69 69.00 1 1 4.39 1.28 0.00	* Const MVA Q MVAR 0.000000		40 01 1 39 12 31 0 40 01 1 39 12 31 0
126296 RAM PAR 345.00 G0 1 0.00 0.00 0.00	Const CUR P MW 0.000000		
126297 RAMAPO 345.00 G0 1 0.00 0.00 0.00	Const CUR Q MVAR 0.039502		0 00 0 0 00 0 0 0 GMD LOAD
126297 RAMAPO 345.00 G1 1 0.00 0.00 0.00			0 00 0 0 00 0 0 GMD LOAD
146769 RAMP138 138.00 G0 1 0.00 0.00 0.00	Const Y P MW 0.000000		0 00 0 0 00 0 0 0 GMD LOAD
146769 RAMP138 138.00 G1 1 0.00 0.00 0.00	Const Y Q MVAR 0.000000	=	0 00 0 0 00 0 0 0 GMD LOAD
130768 WATRC230 230.00 G0 1 0.00 0.00 0.00	Long identifier GMD LOAD		0 00 0 0 00 0 0 0 GMD LOAD
130768 WATRC230 230.00 G1 1 0.00 0.00 0.00			0 00 0 0 00 0 0 GMD LOAD
130838 OAKDL115 115.00 G0 1 0.00 0.00 0.00 1 130807 WESTOVER115 115.00 G0 1 0.00 0.00 0.00	Owner 0		0 00 0 0 00 0 0 GMD LOAD
130839 0AK2M115 115.00 G0 1 0.00 0.00 0.00	zsorcr 0.000000		0 00 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0
130840 OAK3M115 115.00 G0 1 0.00 0.00 0.00	zsorci 0.000000		0 00 0 0 00 0 0 0 0 0 MD LOAD
130756 STOLE345 345.00 G0 1 0.00 0.00 0.00			0 00 0 0 00 0 0 GMD LOAD
130756 STOLE345 345.00 G1 1 0.00 0.00 0.00	mbase 0.000000		0 00 0 0 00 0 0 0 GMD LOAD
135273 DUNKIRK1 115.00 G0 1 0.00 0.00 0.00	Source Current [r] 0.000000		0 00 0 0 00 0 0 0 GMD LOAD
135273 DUNKIRK1 115.00 G1 1 0.00 0.00 0.00			0 00 0 0 00 0 0 GMD LOAD
135279 NORCNGEN 115.00 G0 1 0.00 0.00 0.00			0 00 0 0 00 0 0 GMD LOAD
135298 INDEK-OL 115.00 GO 1 0.00 0.00 0.00 135450 GRDNVL1 115.00 GO 1 0.00 0.00 0.00 0.00	Motor P MW 0.000000		0 00 0 0 00 0 0 0 0 GMD LOAD
135450 GRDNVLI 115.00 G1 1 0.00 0.00 0.00	Motor Q MVAR 0.000000		0 00 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0
135450 GRDNVL1 115.00 G2 1 0.00 0.00 0.00	In Service date 0		0 00 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0
204685 27ALBURTIS 230.00 G0 1 0.00 0.00 1			0 00 0 0 00 0 0 GMD LOAD
218350 BRANCHBG 230.00 G0 1 0.00 0.00 0.00	Out of Service date 0		0 00 0 0 00 0 0 0 GMD LOAD
218350 BRANCHBG 230.00 G1 1 0.00 0.00 0.00	Shed 0.000000		0 00 0 0 00 0 0 0 GMD LOAD
218350 BRANNERBE 230.00 C2 1 0.00 0.00 0.00			
find fill insert delete	Pshed 0.000000		sort origVal refresh done
	nonconf 0	T	
	Printer Prev	ок	
	Find Next	Cancel	



Fully EPCL compatible

- GMD structures are exposed similarly to other PSLF data structures
- User is provided with default EPCLs for detailed analysis
- User's guide has easy copy and paste samples of EPCL code for GMD analysis

Allows the same automation flexibility already available in other PSLF tools

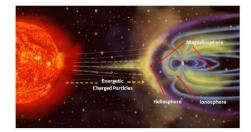


GMD manual

- Describes how to set up a GMD case
- Description of GMD data
 structures
- EPCL code samples

Geomagnetic Disturbance Analysis in GE PSLF - User's Manual

September 2013



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PSLF Demo



FYI don

From: FERC - State Relations [mailto:FERCStateRelations@ferc.gov]
Sent: Wednesday, December 23, 2015 7:52 AM
To: Cameron Schilling <Cameron.Schilling@ferc.gov>
Subject: FERC Technical Conference - GMD

See below for more details on an upcoming technical conference regarding geomagnetic disturbance events.

December 23, 2015 - FERC To Convene a Technical Conference on Reliability Standard for Transmission System Planned Performance for Geomagnetic Disturbance Events on March 1, 2016 <u>Notice</u> <u>Errata Notice</u> <u>Event Details</u>

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