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A SOLID-STATE TRANSFORMER FOR ELECTRIC POWER GRID HEMP/GMD MITIGATION

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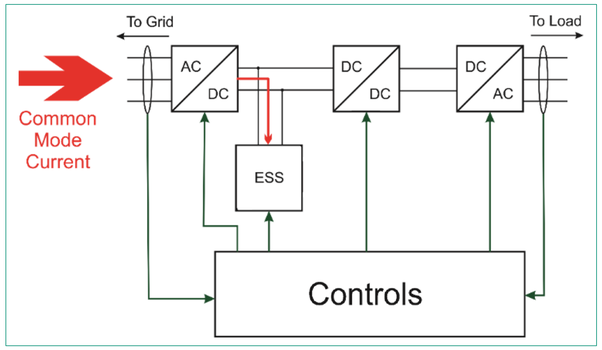
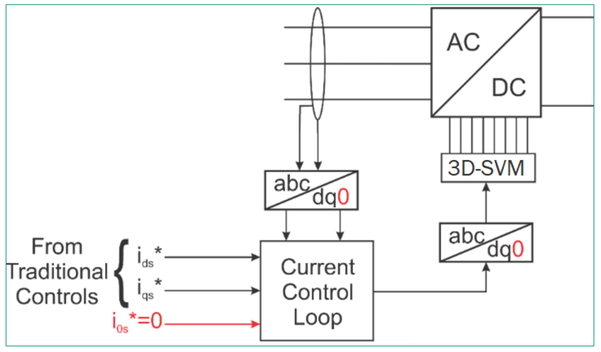
Abstract

- A high altitude electromagnetic pulse (HEMP) or other similar geomagnetic disturbance (GMD) has the potential to severely impact the operation of large-scale electric power grids
- These electromagnetic insults result in low-frequency common-mode (CM) currents which impact the performance of key power system components, such as large power transformers
- This work proposes a solid-state transformer (SST) that can replace susceptible equipment and improve grid resiliency by safely absorbing these CM insults

Solid State Transformer

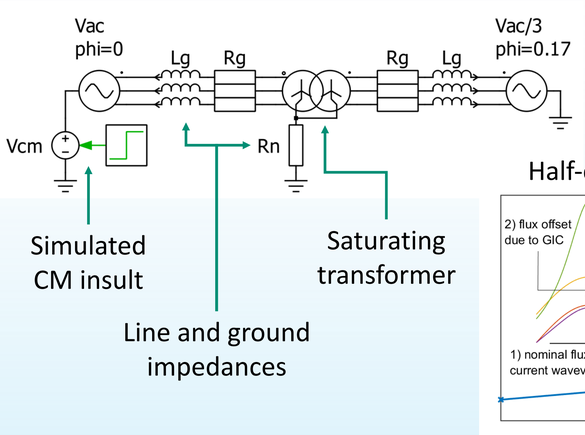


Control of CM Current

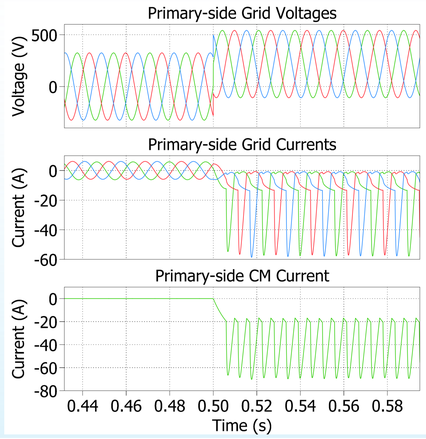


Conventional Transformers and Half-cycle Saturation

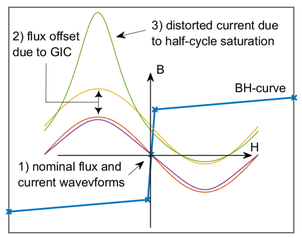
- 1000's of large power transformers make up the backbone of today's grid by connecting the loads of the system (factories, businesses, homes) to generation through a high-voltage transmission network
- Although relatively efficient and reliable, conventional transformers are susceptible to low-frequency CM currents due to their design based on a magnetic core
- These low frequency currents lead to half-cycle saturation resulting in distorted ac waveforms, increased losses, and the potential for thermal damage [1,2]



Simulation Results

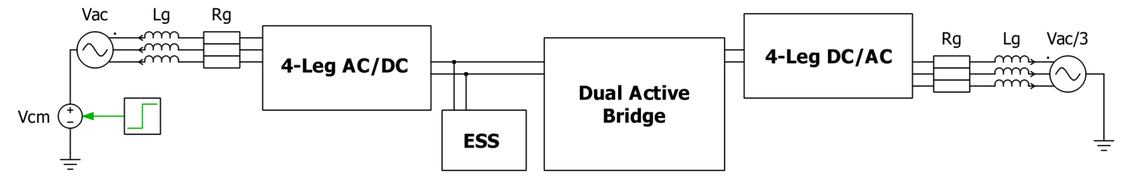


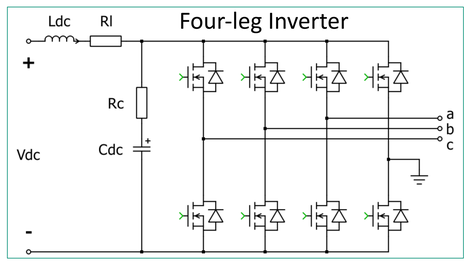
Half-cycle saturation

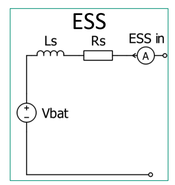


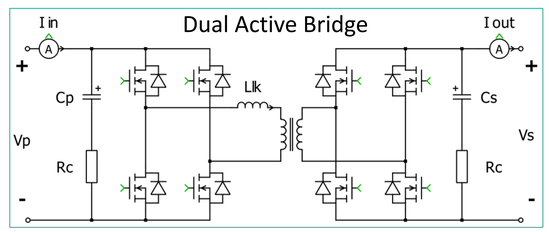
HEMP/GMD Resilient SST

- Solid-state transformers (SSTs) are an emerging technology that aims to supplant conventional magnetic transformers with designs based on power electronics
- SST will enable a more flexible, reliable, and resilient grid through advanced circuit designs, novel semiconductor devices, and advanced control techniques [3]
- By utilizing power electronics and energy storage, an SST can be made immune to HEMP/GMD insults while maintaining nominal ac input/output behavior



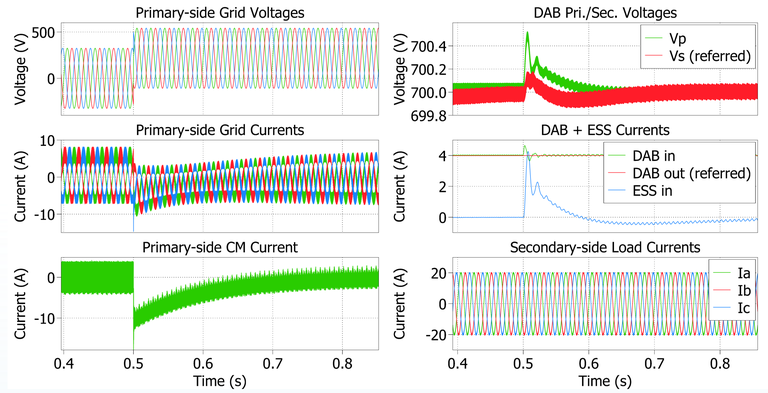






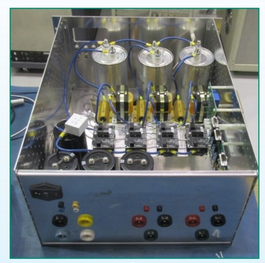
Simulation Results

- CM insult applied at t = 0.5 seconds
- SST controls quickly bring CM current back to zero
- CM energy absorbed by ESS, secondary-side unaffected by insult

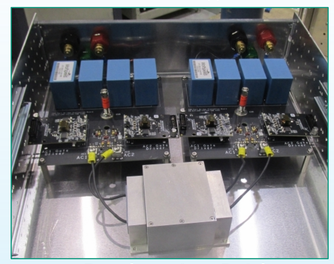


Hardware Build

- 480Vac/120Vac 10 kW scaled test unit under development
- Preliminary testing of 4-legged AC/DC converters shows similar fast response to applied CM insult



4-legged AC/DC Converter



Dual-active Bridge

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[1] J. G. Kappenman, "Geomagnetic Storms and Their Impact on Power Systems," in IEEE Power Engineering Review, vol. 16, no. 5, pp. 5-, May 1996
[2] H. M. Pennington, C. J. Hanley and J. D. Rogers, "Toward an Electromagnetic Event Resilient Grid," in Proceedings of the IEEE, vol. 109, no. 4, pp. 315-319, April 2021
[3] Solid State Power Substation Technology Roadmap, U.S. DOE Office of Electricity Transformer Resilience and Advanced Components (TRAC) Program, 2020

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