AGENDA, June 18, 2024 HVDC-Learn Meeting

1. Introductions - All
2. DOE comments - DOE
3. Logistical - McCalley
   a. Current-Pending Support
   b. Project website
4. Pressing issues - McCalley
   a. Project logo
   b. Module design & development – principles & process
   c. Module list
   d. First PAB meeting
   e. First Bridgeport meeting
5. Jupyter approach to module development – Hantao Cui
6. Current priorities - McCalley

Logistical - Current Pending/support (CPS)

- **From DOE Contract (Special Terms and Conditions, Term 45 Current & Pending Support)**: ISU must ensure all PIs and senior/key personnel at the recipient and subrecipient level, are aware of the requirement to submit updated current and pending support (CPS) disclosure statements to DOE, within 30 calendar days of change in current and pending support.
- **Approved Approach**: Limit recipient and subrecipient CPS updates so that they are required only if a recipient or subrecipient
  - is awarded a new project
  - that will result in one month per year, or more, of their time during the duration of the HVDC-Learn project.

➔SEND ME UPDATED CPS DOCUMENT IF YOU GET NEW AWARD REQUIRING≥1 MNTH/YR OF YOUR TIME.

Logistical - Project Website (not module website)

home.engineering.iastate.edu/~jdm/hvdclearn/index.htm

Note: this website is for storing project logistical information (it is not where modules will reside).

Contains slides of all meetings (team, PAB, & Bridgeport)
Bookmark it.

Home Page for the
HVDC-LEARN project
3 year project (2024-2027)
Funded by the US Department of Energy
(Office of Energy Efficiency and Renewable Energy)

Modules for Maturing HVDC Electric Transmission Knowledge

Project information;

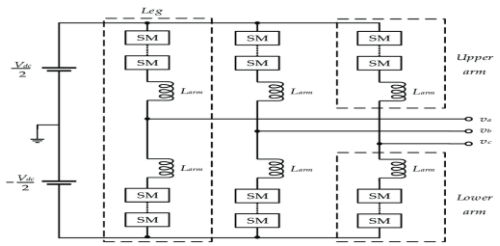
- ▶Short project description
- ▶One slide summary
- ▶Slide decks from project team meeting:
  - May 31, 2024
  - June18, 2024
- ▶Slides from Project Advisory Board Meetings:
- ▶Slides from Bridgeport Meetings:

PROJECT LOGO

HVDC Cable

Converter

HVDC LEARN



Modules for Maturing HVDC Electric Transmission Knowledge

Offshore Wind

Overhead HVDC

Descriptive statement

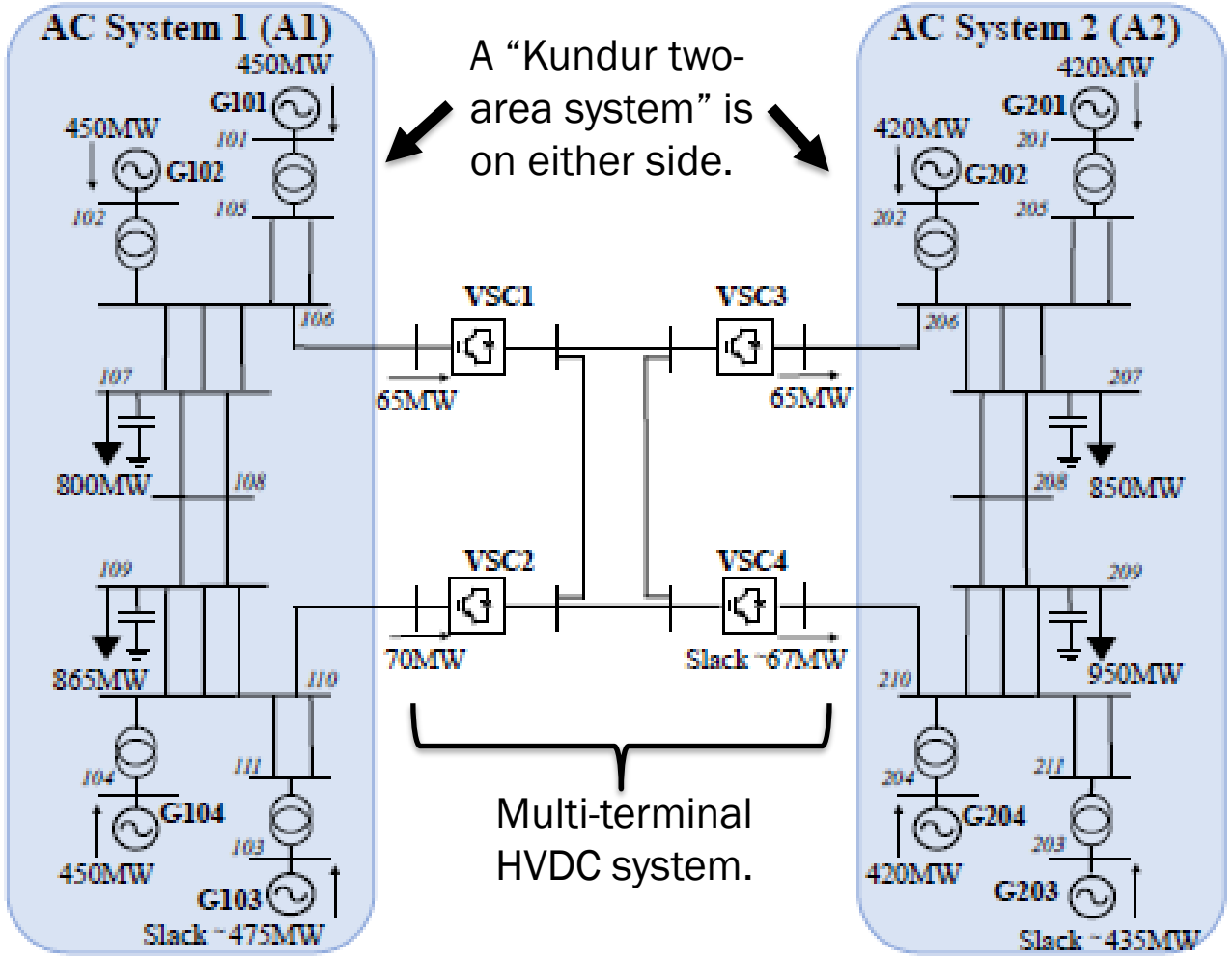
➔I WILL SUBMIT THIS TO DOE ON 7/10, SO IF YOU HAVE SUGGESTIONS, SEND BY 7/10.

Module development principles

1. Team-aware: The design/content of a module, though led by one of us, is influenced by all of us. This occurs in four ways:
   a. We develop and share abstracts with bulleted contents for all modules, early in the project.
   b. We maintain a project topical index that identifies for all topics, occurrences in all modules.
   c. Although we do not restrict overlap/redundancy, we try to be aware of it and reference treatments of the same topic in other modules.
   d. The review process enables that all project team members see what is in every module.
2. Multi-stage review process: (i) lead-reviewer, (ii) team, (iii) formal review (lead reviewer + 3 others), (iv) course testing and feedback. This process results in modules having substantive and applicable content.
3. Common themes to employ:
   a. Treat both onshore (first) & offshore (last) applications in your module.
   b. Compare/contrast with (generally more familiar) AC transmission.
   c. Illustrate using a common test system (see next slide).

Module development principles ➔possible test system

I invite suggestions for other possible test systems.



- P. Kundur, Power System Stability and Control. New York, NY, USA: McGraw-Hill, 1994.
- C. Canizares *et al.*, "Benchmark Models for the Analysis and Control of Small-Signal Oscillatory Dynamics in Power Systems," in *IEEE Transactions on Power Systems*, vol. 32, no. 1, pp. 715-722, Jan. 2017, doi: 10.1109/TPWRS.2016.2561263.
- Q. Zhang, J. McCalley, *et al.*, "Primary Frequency Support Through North American Continental HVDC Interconnections With VSC-MTDC Systems," in *IEEE Transactions on Power Systems*, vol. 36, no. 1, pp. 806-817, Jan. 2021, doi: 10.1109/TPWRS.2020.3013638.

Module development process

STEP	DESCRIPTION	TIME
1	Develop abstracts and bulleted list of content for all modules.	3 wks (now)
2	Project advisory board (PAB) considers table of modules together with abstracts. Some PAB members may volunteer to serve as co-authors of certain modules.	By end of Q1
3	Development process:	
3a	Lead author develops V1a (competencies & objectives identified; fairly well-developed intro, section headers, some writing in sections, some figures/tables).	0.5 months
3b	Share w/ lead reviewer (& any co-author); develop V1b (fairly mature) based on comments.	3 months
3c	Share w/ team, address comments from team, authors complete module; this is V2.	1 month
4	Review & testing process:	
4a	Submit V2 for review by 4 reviewers: lead reviewer (coordinates), at least 1 PAB member, & 2 more.	1 month
4b	Develop V3 based on reviewer comments.	1.5 months
4c	Post V3 to publicly available website.	
5	Course-test (in short course and/or other course).	
5a	Develop V4.	
5b	Repost to publicly available website (with periodic revision).	

Sample Abstract

I am asking for an abstract for all modules by 7/10/2024. This will be useful for the following reasons:

1. It gives PAB a good understanding of what we intend, enabling them to provide more substantive comments.
2. It provides each of us with understanding of what modules might overlap with our own.
3. The abstract will be located in the front of the module, and so after 7/10 we will be able to say that all modules have been started.

Module 7a
Point-to-Point HVDC Configurations

Primary Author: James McCalley, Iowa State University
Email Address: jdm@iastate.edu
Co-author:
Last Update: June 18, 2024

Prerequisite Competencies:
1. Motivating needs for high-capacity electric transmission
2. HVDC converter types and operations as found in Modules 1a, 1b, 1c.

Module Objectives:
1. Identify features of point-to-point HVDC transmission
2. Distinguish from multi-terminal HVDC systems.
3. Identify point-to-point applications and describe implementations of each

7a.1 Abstract

In contrast to multi-terminal HVDC systems, point-to-point (P2P) HVDC transmission connects only two converter terminals via a direct current transmission path. They may connect two asynchronous AC systems, or they may provide a DC transmission path within a single AC system. P2P is the oldest HVDC design, having seen application since the early 1950s, and with over 200 implementations worldwide, it is by far the most common design. Many new P2P HVDC projects are being planned or built today.

The objective of this module is to characterize P2P HVDC designs. To do so, we begin in Section 7a.2 by summarizing point-to-point design basics in terms of types of components, e.g., converters, protection, filters, and conductors, and in terms of configuration (monopole, bipole, and tripole). Section 7a.3 describes four different P2P applications, including overhead, back to back, underground, and submarine, and provides descriptive examples of each. Section 7a.4 describes P2P applications for offshore wind. Section 7.4a.5 summarizes the main learning points of this module and concludes.

MODULE COMPLETION SCHEDULE

Prjct team member	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
O1, H. Cui				Mod 2b				Mod 4c				Mod 10a
M1, X. Fang		Mod 1c					Mod 3c				Mod 10d	
C1, J. Enslin							Mod 5c					
T1, E. Hines					Mod 11a				Mod 1d		Mod 12a	
UT1, F. Li		Mod 1b						Mod 9e				
T2, P. Lof				Mod 1a				Mod 9a				
I1, J. McCalley		Mod 9b	Mod 7a			Mod 9c		Mod 9d		Mod 10b		Mod 11b
V1, A. Mehrizi-Sani			Mod 2a		Mod 3b			Mod 4b	Mod 5b		Mod 5e	Mod 10c
C2, M. Nazir				Mod 4d								Mod 3a
T3, A. Stankovic								Mod 10e				
UT2, L. Tolbert			Mod 3d			Mod 4a			Mod 5d			Mod 8a
M2, D. Wallace				Mod 5a						Mod 6a		

By 7/10, I need your confirmation on assignment/completion date for lead author & lead reviewer. Also need abstract.

	Confirmation on Assignments	Abstracts
O1, H. Cui	Confirmed	
M1, X. Fang		
C1, J. Enslin		
T1, E. Hines	Confirmed	
UT1, F. Li	Confirmed	
T2, P. Lof		
I1, J. McCalley	Confirmed	7a,
V1, A. Mehrizi-Sani		
C2, M. Nazir		
T3, A. Stankovic		
UT2, L. Tolbert	Confirmed	
M2, D. Wallace	Confirmed	

MODULE LIST

Submit this on 7/10/2024 to DOE. This locks us in.

(yellow to be completed year 1; blue in year 2; white in year 3)

Mod #	Lead-auth /Lead-rvwr	Module title	# of 1-h lectures	Comp date
1. INTRODUCTORY/OVERVIEW COVERAGE, Li				
1a	T2/UT1	Intro to HVDC technology	3	Q4
1b	UT1/T2	Application Guide for HVDC Transmission	3	Q2
1c	M1/T1	Intro to HVDC for offshore wind	3	Q2
1d	T1/C1	HVDC for executives	2	Q9
2. STATION COMPONENTS, Cui				
2a	V1/O1	HVDC reactive power, EMI, and filter design	4	Q3
2b	O1/C1	VSC-HVDC converter station technologies	3	Q4
3. CONVERTERS, Enslin				
3a	C2/C1	Interoperability between different HVDC converter technologies/vendors	3	Q12
3b	V1/M1	Power electronics 101: Fundamentals of switching pwr conv+EMT	3	Q5
3c	M1/UT2	Operation of thyristors & IGBTs in converters	4	Q7
3d	UT2/M1	Modular multilevel converter as HVDC cnvrtr interface and its control	3	Q3
4. CONTROL, Mehrizi-Sani				
4a	UT2/O1	Cnvtr cntrl fundamentals	4	Q6
4b	V1/C2	Dynamic modeling/cntrl of HVDC converters and grid-forming functions	4	Q8
4c	O1/V1	Control of multiterminal HVDC networks	4	Q8
4d	C2/C1	Offshore HVDC cnvrtr grid forming controller design for black start capability	3	Q4
5. HVDC PROTECTION, Nazir				
5a	M2/UT2	HVDC fault management & protection systems	6	Q4
5b	V1/UT1	HVDC measurements, faults, and misoperation	3	Q9
5c	C1/C2	Protection for multi-terminal HVDC networks	3	Q7
5d	UT2/M2	Protection: ability to ride through faults in HVDC	3	Q9
5e	V1/UT1	Cybersecurity in HVDC systems	3	Q11
6. HVDC LINE & CABLE TECHNOLOGIES, Wallace				
6a	M2/C1	Insulation - HVDC cables	5	Q10
7. POINT-TO-POINT HVDC CONFIGURATIONS, McCalley				
7a	I1/UT1	Onshore & offshore apps	2	Q3
8. MULTI-TERMINAL HVDC NETWORKS, Tolbert				
8a	UT2/O1	Design/operation of multiterminal HVDC grids	3	Q12
9. PLANNING AND DESIGN, McCalley				
9a	T2/O1	HVDC in pwr sys.; meshed HVDC systems	3	Q8
9b	I1/T1	Processes for planning & building offshore HVDC	3	Q2
9c	I1/T1	Expansion planning for offshore HVDC, topology/ capacity design for HVDC interregional transmission	5	Q6
9d	I1/M1	Macrogrid & HVDC offshore networks	4	Q8
9f	UT1/T2	A long-term planning study of offshore HVDC	4	Q8
10. HVDC SYSTEM SIMULATION & ANALYSIS, Fang				
10a	O1/C2	Hardware-in-the-loop electromag transient sim	3	Q12
10b	I1/T3	Large-sys analysis of multiterminal HVDC grids	4	Q10
10c	V1/M1	Frequency-dependent representation of AC syst	4	Q12
10d	M1/O1	Modeling of HVDC grids	6	Q11
10e	T3/I1	Reactive power & harmonics	6	Q8
11. REGULATORY/PERMITTING PROCESSES & PROC, McCalley				
11a	T1/T2	Offshore transmission development processes	3	Q5
11b	I1/UT1	HVDC right-of-way	3	Q12
12. ENERGY EQUITY & ENVIRONMENTAL JUSTICE, Hines				
12a	T1/V1	Effects of HVDC on enrgy equity & env. justice.	3	Q11

Information on Project Advisory Board

Current PAB list has 33 people and is available here:
https://docs.google.com/spreadsheets/d/1swCIISVI8wRIbIAJQ1K-uS2uhCZP4fWX/edit?gid=2023692464#gid=2023692464

I have organized two upcoming PAB meetings, per the below, with 31 PAB members committed to attend. You may attend or not, as you like.

Communication to PAB, sent 6/17/2024:

I am following up on the below mail last week for the HVDC-Learn Project Advisory Board (PAB) meeting date/time.

Having assessed the doodle poll response, it will be better to maximize attendance if I hold the same PAB meeting twice. Please attend one of them. The same information will be provided in both. The meeting times and corresponding Zoom links are below:

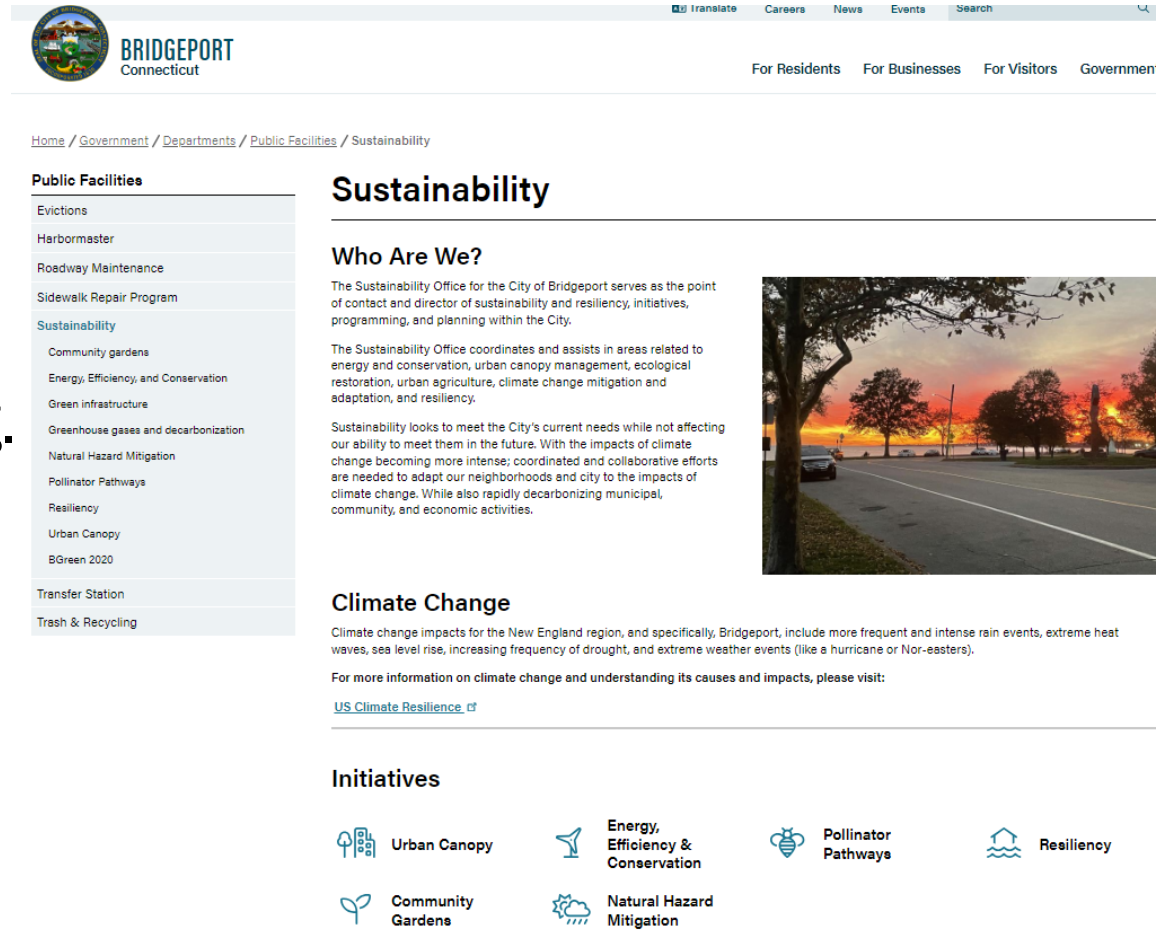
- Tuesday, June 25, 10am-11am CDT (GMT-5), Zoom Link: https://iastate.zoom.us/j/93544759326?pwd=jisQQALG0zwIeiUKtmkjQAdBnVg8Fx.1
- Monday, July 1, 11am-12pm CDT (GMT-5), Zoom Link: https://iastate.zoom.us/j/95424307867?pwd=jejbwg6bSWUVce6MXbOpQI52bzp72w.1

Also, for your convenience, I have attached Outlook reminders for both meetings with the Zoom link in them.

The purpose of this meeting is to introduce you to the project deliverables and the process, and to communicate my request to you for your role in this effort. On behalf of the 7-university, 12-faculty project team, I express appreciation to you for your willingness to participate; I think you will find it useful. Let me know if you have any questions in advance of the meeting.

FIRST BRIDGEPORT MEETING

1. Contact is Chadwick Schroeder, Bridgeport Sustainability Manager.
2. Am coordinating now to visit him in July.
   a. 1 hr discussion where I present team & project basics but also indicate availability of our team to work with Bridgeport in other ways as well.
   b. Chadwick to also present/characterize Bridgeport current sustainability needs.
   c. Will be virtual; need 75% of us participating.
3. Objective: In partnership w/ Bridgeport, identify ways to decrease energy burden (energy cost/income) while enhancing sustnblty & mitigating envrnmntl impacts.
   - Characterize existing conditions
   - Identify choices
   - Understand community concerns
   - Develop useful materials



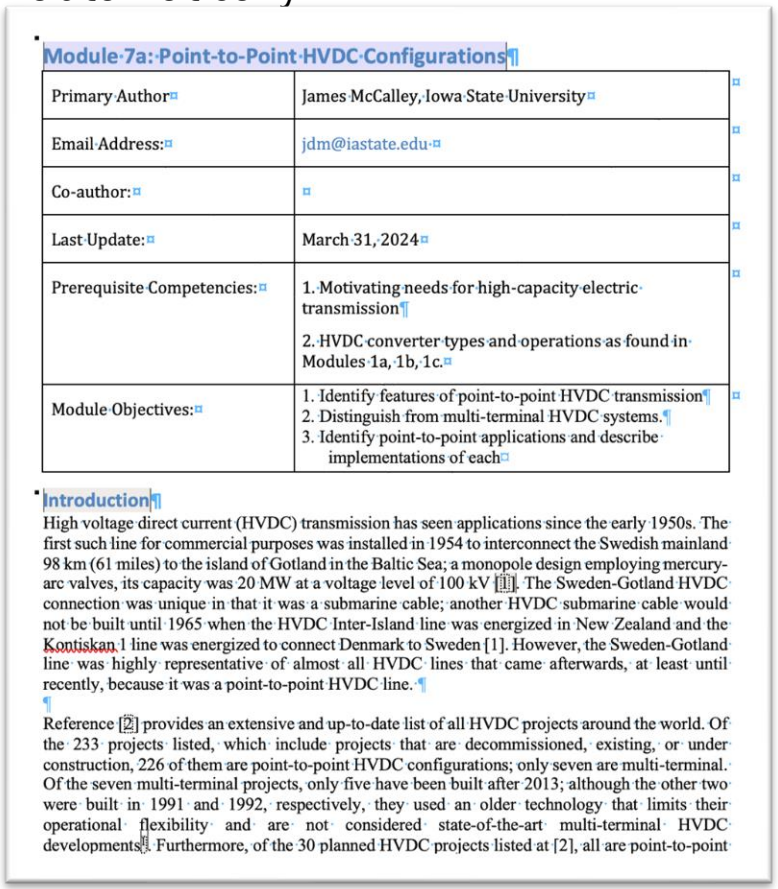
Word-based module template for Jupyter Book presentation

Philosophy:

- Provide a template for team members to write the materials for modules
- Make the learning curve as smooth as possible
- Organize and present the modules in a website, automatically

How to:

- Follow an MS Word Template and start writing modules
  - There is no need to learn Jupyter if not highly desirable
- For those looking to use Jupyter Notebook instead of Word, contact Hantao



Module 7a: Point-to-Point HVDC Configurations

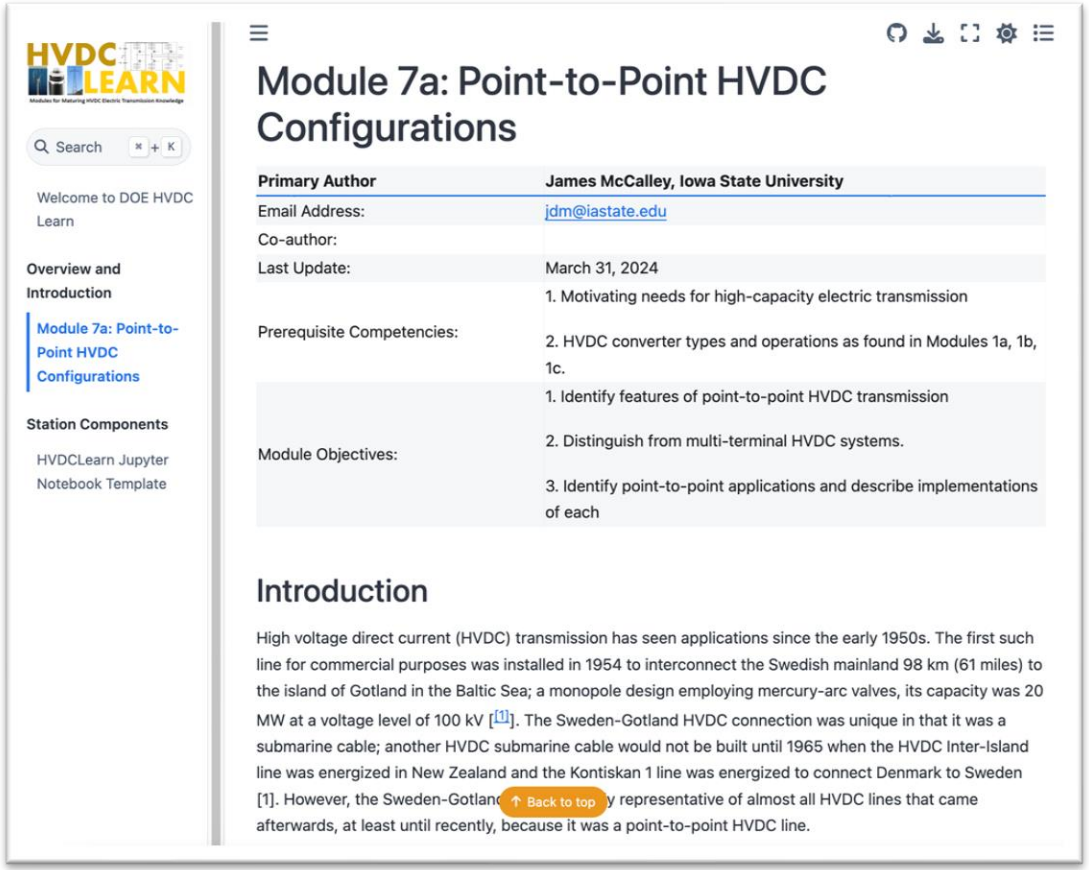
Primary Author	James McCalley, Iowa State University
Email Address:	jdm@iastate.edu
Co-author:	
Last Update:	March 31, 2024
Prerequisite Competencies:	1. Motivating needs for high-capacity electric transmission 2. HVDC converter types and operations as found in Modules 1a, 1b, 1c.
Module Objectives:	1. Identify features of point-to-point HVDC transmission 2. Distinguish from multi-terminal HVDC systems. 3. Identify point-to-point applications and describe implementations of each

Introduction

High voltage direct current (HVDC) transmission has seen applications since the early 1950s. The first such line for commercial purposes was installed in 1954 to interconnect the Swedish mainland 98 km (61 miles) to the island of Gotland in the Baltic Sea; a monopole design employing mercury-arc valves, its capacity was 20 MW at a voltage level of 100 kV [1]. The Sweden-Gotland HVDC connection was unique in that it was a submarine cable; another HVDC submarine cable would not be built until 1965 when the HVDC Inter-Island line was energized in New Zealand and the Kontiskan 1 line was energized to connect Denmark to Sweden [1]. However, the Sweden-Gotland line was highly representative of almost all HVDC lines that came afterwards, at least until recently, because it was a point-to-point HVDC line.

Reference [2] provides an extensive and up-to-date list of all HVDC projects around the world. Of the 233 projects listed, which include projects that are decommissioned, existing, or under construction, 226 of them are point-to-point HVDC configurations; only seven are multi-terminal. Of the seven multi-terminal projects, only five have been built after 2013; although the other two were built in 1991 and 1992, respectively, they used an older technology that limits their operational flexibility and are not considered state-of-the-art multi-terminal HVDC developments. Furthermore, of the 30 planned HVDC projects listed at [2], all are point-to-point

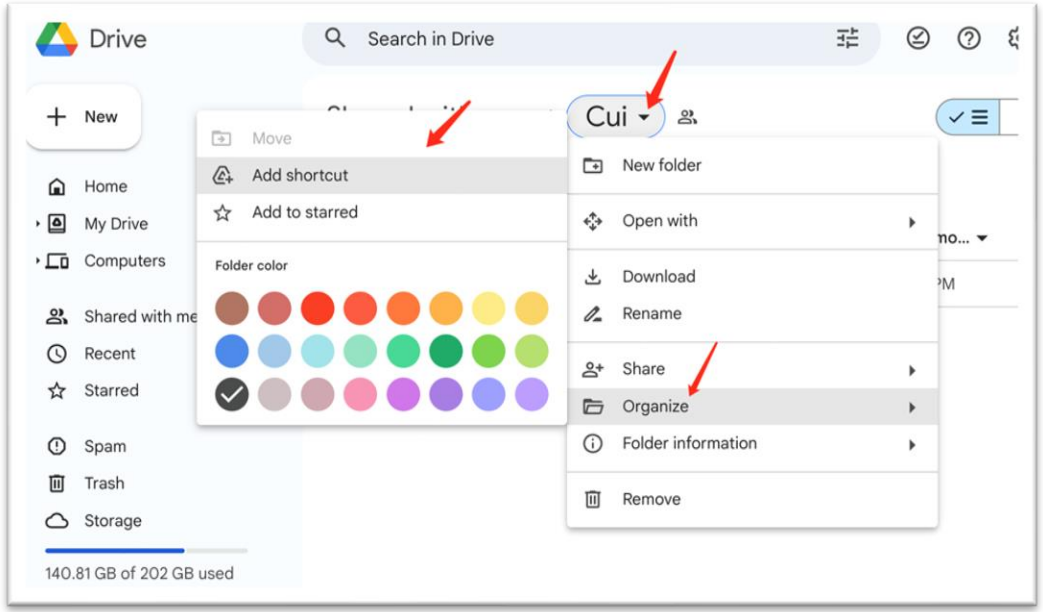
Example module in the Word template

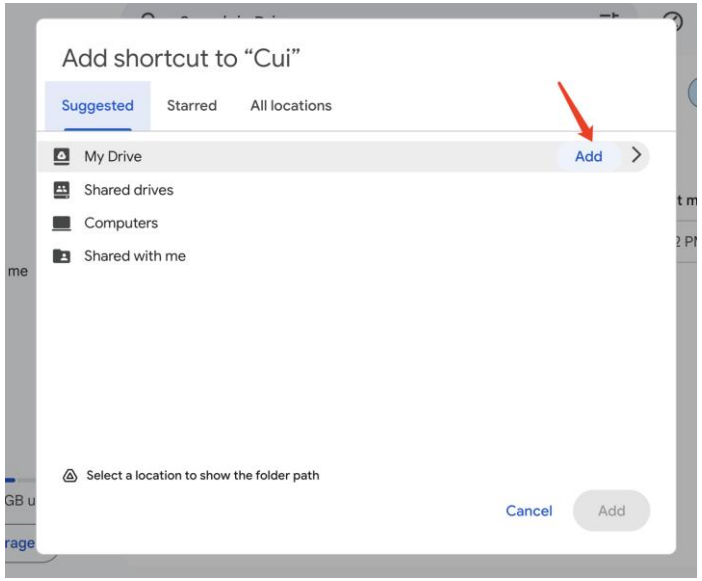


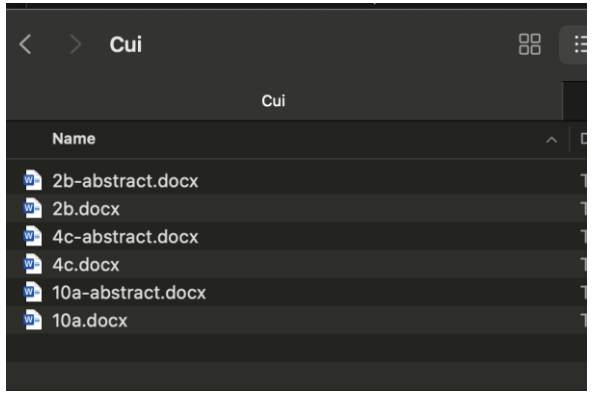
Rendered module by Juputer Book

Collaboration using Google Drive

- I'd like to ask you to install Google Drive and edit the module file from there.
- It will allow me to check the format at the early stage and fix issues with the Jupyter Book building as you develop the module.
- You will receive an email with a link to Google Drive. The folder is in your name.
- Click "Open". You may need to login with your Google account.
- Next, add a shortcut to the shared folder by following the screenshot on the right. Hover over "My Drive" and click "add".
- Finally, install Google Drive and set up file sync. You will find the folder in your name in Google Drive. You can now edit the module file locally.
- If you need technical assistance, please contact Hantao (hcui9@ncsu.edu)







Action items:

- Work on the abstracts for your modules
- Rename the file to *ModuleNumber-abstract-V1.docx* to indicate its ready-for-review status

Indication of Review Status

- Rename the file to V1a, V1b, V2a, … to indicate the versions. V2 is the version as review-ready.

What are our current priorities?

1. All modules: Develop half-page abstract with major sections identified and send to me by 7/10 (all).
2. Start on year 1 modules:
   - McCalley, 7a – Pt 2 pt onshore & offshore apps, Q1←EARLY COMPLETION OF THIS (AND DISTRIBUTE!!!)
   - Fang, 1c - Intro to HVDC for offshore wind, Q2
   - Li, 1b - Application Guide for HVDC Transmission, Q2
   - Lof, 1a - Intro to HVDC technology, Q4.
   - Mehrizi-Sani, 2a - HVDC reactive power, EMI, and filter design, Q3
   - Tolbert, 3d - Modular multilevel converter as HVDC cnvrtr interface and its control, Q3.
   - Wallace, 5a - HVDC fault management & protection systems, Q4.
   - Cui, 2b - VSC-HVDC converter station technologies, Q4
   - Nazir, 4d - Offshore HVDC cnvrtr grid forming controller design for black start capability, Q4.
3. Comment on project logo and module summary table per slide 7 by 7/10 (all).
4. Submit project logo and module summary table to DOE by 7/10 (McCalley).
5. Develop website (Cui/McCalley).
6. Begin developing short course (Fang).
7. First PAB meeting: Tuesday June 25 11am-12 CT and July 1 11am-12 CT (McCalley).
8. Organize visit to/meeting with Bridgeport (McCalley/Hines).
9. Initiate multischool HVDC offshore design projects (Nazir).
10. Tell me if you are hiring student – 3 need to be hired by end of Q2, 1 of them female, w/div-search (have heard only from Hines on this).