DOE/OE Transmission Reliability Program

Analysis of Multi-terminal HVDC Systems

Harold Kirkham

Pacific Northwest National Laboratory

harold.kirkham@pnnl.gov

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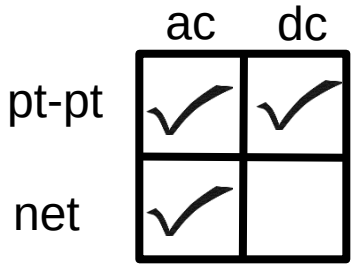
Project Objective (Background)

- This is a startup effort, based on recognition that
  - ac lines exist
  - ac networks exist
  - dc lines exist
  - dc networks do *not* exist. DC systems are point-to-point*
  - The advantages of dc apply to networks as well as point-to-point
  - The advantages of networks apply to dc as well as ac



  - It makes sense to look at why this is, why there should be dc networks, and what one could "do" with such a thing as a dc network

* With just two exceptions of the ~180 that have been built

Project Objective

- Increase “comfort level” for dc grids
- That is, show that multi-terminal HVdc systems are both *advantageous* and *feasible*
- Issues to explore include
  - Evolution / Topology of dc grid
  - Operation / Controllability of a dc grid
  - Need for breaker on dc side
  - Handling of islanded operation
  - Protection schemes for dc grid
  - Effects of cable capacitance
  - Communication infrastructure

Project Objective

This is evidently a “hot topic.”

This was posted on Power Globe on June 17:

Applicants are invited for Early Stage Researcher (ESR) positions in the Marie-Curie Multi-terminal DC grid for offshore wind, initial training network (MEDOW ITN) at CITCEA-UPC, CINERGIA, and ALSTOM WIND. The following positions are available:

- ESR4 Control of multi-terminal HVDC systems for offshore wind power, CITCEA-UPC
- ESR5 Power converter design and control for multi-terminal DC grids, CINERGIA
- ESR6 Control of wind farms interfaced to multi-terminal DC systems, ALSTOM WIND

Major Technical Accomplishments

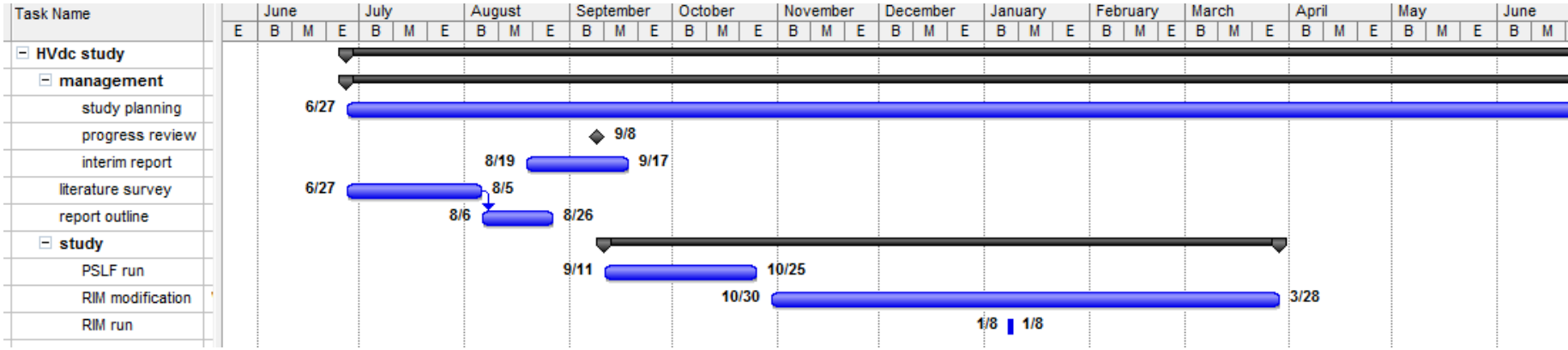
- Within the remaining three months of FY 13 we will
  - Firm up plans, staffing
  - Perform literature survey
  - Outline major elements of a report
  - Begin study
- Within remaining months of a 12-month effort, we will
  - Continue study effort
  - Hold one (interim) review meeting, possibly by telecon
  - Complete a report
  - Hold one further review meeting
  - Identify and propose follow-on work (if appropriate)

Deliverables

- Deliverables for activities to be completed under FY13 funding
  - **Work plan** for review and comment
  - **Letter Report** on literature survey
  - **Interim Review** meeting

Schedule

- schedule for activities to be completed under FY13 funding



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Risk Factors

- Risk factors affecting timely completion of planned activities as well as movement through RD&D cycle:
- There is negligible risk regarding
  - Planning and staffing, literature survey, report outlining
- There seems to be negligible risk regarding
  - Demonstrating the advantages of networking dc lines
- There is a possibility that
  - We find some reason that dc networks are not technically feasible – they rely on some infeasible switching speed or some impossible calculation to be done, for example
- We regard this as low risk

Follow-on

- Early thoughts on follow-on work that should be considered for funding in FY14
- Follow-on ideas in three categories
  1. Continue the planned work to extend to problems of bulk supply that are particularly suited to solution by dc networks. Such work is predicated on the idea that we WILL find interesting and untapped applications.
     - River-based deployment
     - City-ring configuration with bulk infeed capability
     - Large-scale congestion management (OH line based)

Follow-on

2. Start new aspects of the study, based on the potential of the developing technology. Some possibilities are
   - Extend the work beyond the "steady-state" emphasis of our early work (bulk power, congestion management, cascade limiting etc) to look at faster response notions such as damping control
   - Collaborate with WECC in their modeling efforts for HVdc (see previous item)
   - Start looking at software needed to incorporate HVdc networks into system operation, from planning to dispatching to . . .
   - Investigate protection systems for dc networks
   - Start looking at split-grid options (frequency-control?)
   - Look at specific solutions for wind, particularly offshore

3. Extend the work to lower levels of the power delivery system, even down to distribution