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Optimization of railway power supply systems - operation and design

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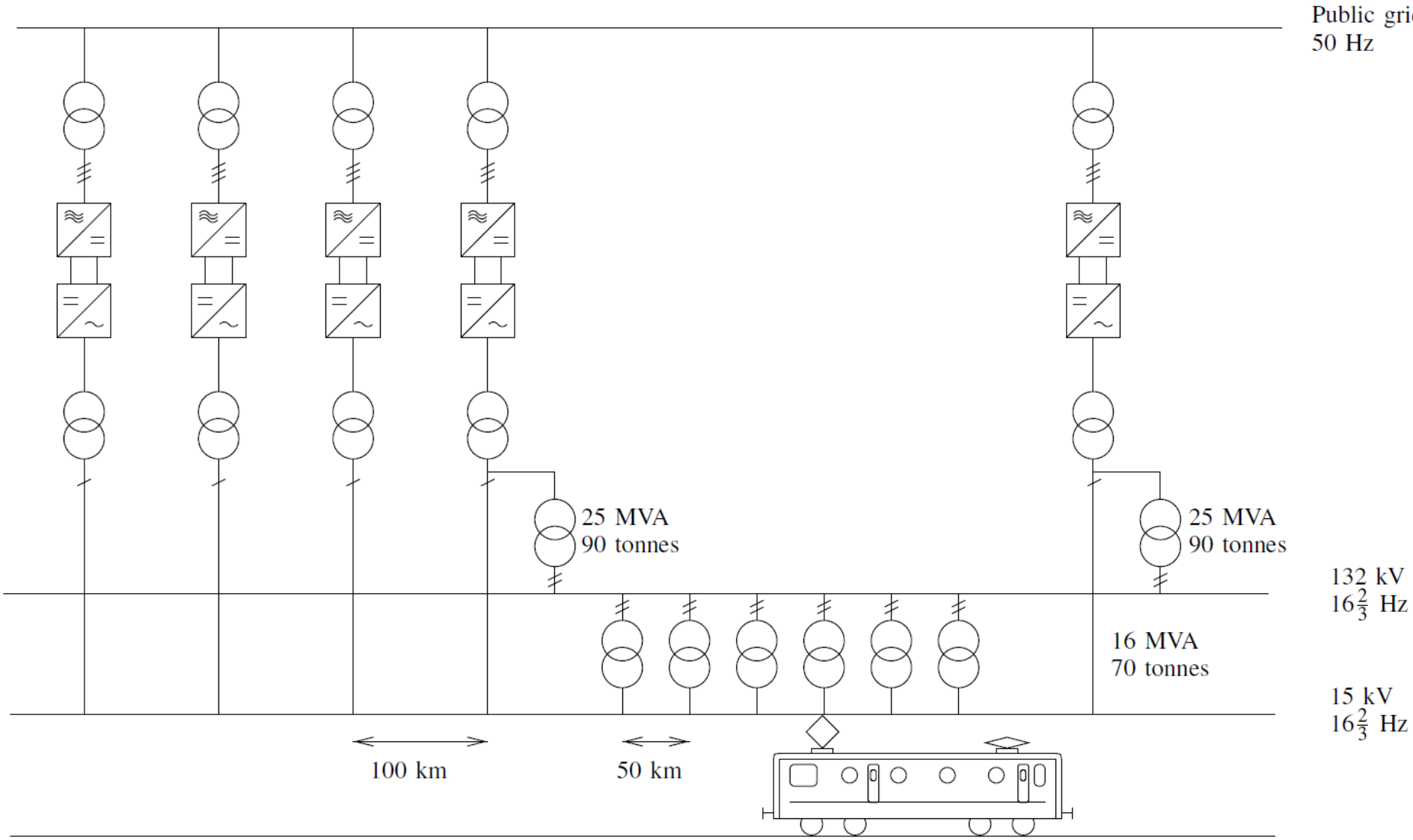
Outline

- Background
- Brief summary of results in thesis
  - Converter Usage
  - Operation Part
    - Static loads – HVDC and OPF
    - Moving loads
      - Simulator (Licentiate)
      - Fixed node model
  - Design part – placement of converters
- Future work
  - Being done
  - Elektra application
  - General thoughts
- Time for questions

Background
Today's Swedish railway power supply system



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Background
Problems encountered today

- Domestically
  - Urban areas – lack of installed power
    - Peak hours
    - Grid more meshed, comparatively cheap
  - Rural areas – voltage drops
    - When traffic occurs it is heavy
    - Uneconomical to dimension for peaks
- Internationally
  - The two above
  - Transformer-feeding of railway
    - Imbalances
    - Harmful for weak grids
      - Expansion in the US, for example

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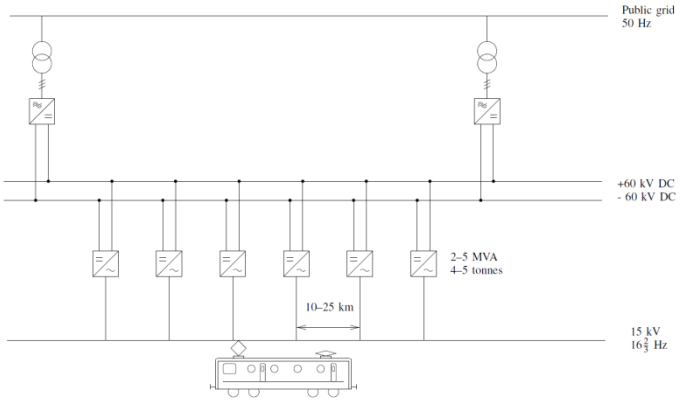
Brief summary of results in thesis
Converter Usage

- Many countries use transformers for feeding
  - 50 Hz/60 Hz
  - In the Nordic countries
    - Denmark, Finland
- Converters allow feeding from weaker grids
  - Sweden/Norway: feeding railway from 22 kV
- Regeneration is optional
  - Sweden: Rotary converters will regenerate
- Two-sided feeding & interconnection possible
  - Reduced catenary currents
  - Approximately halved installed power per substation
  - Public grid peak loads also “halved”
  - China sees this – not the solution
- Symmetrical loads

Brief summary of results in thesis
Operation Part

- Static loads – HVDC and OPF
  - 132 kV grid hard to expand
    - Land use & permissions overhead lines
    - AC cables may cause problems
    - DC cables then?
  - HVDC Light transmission line
    - Buriable
    - Low losses
    - Voltage source converters (VSC) needed => controllability
      - Optimal power flow (losses, for example)
      - Optimal commitment (idling losses)
    - Outperforms 132 kV grid when regenerating
    - Verified theoretically for static loads
      - Papers & Masters Thesis
  - AT catenaries solves some problems temporarily



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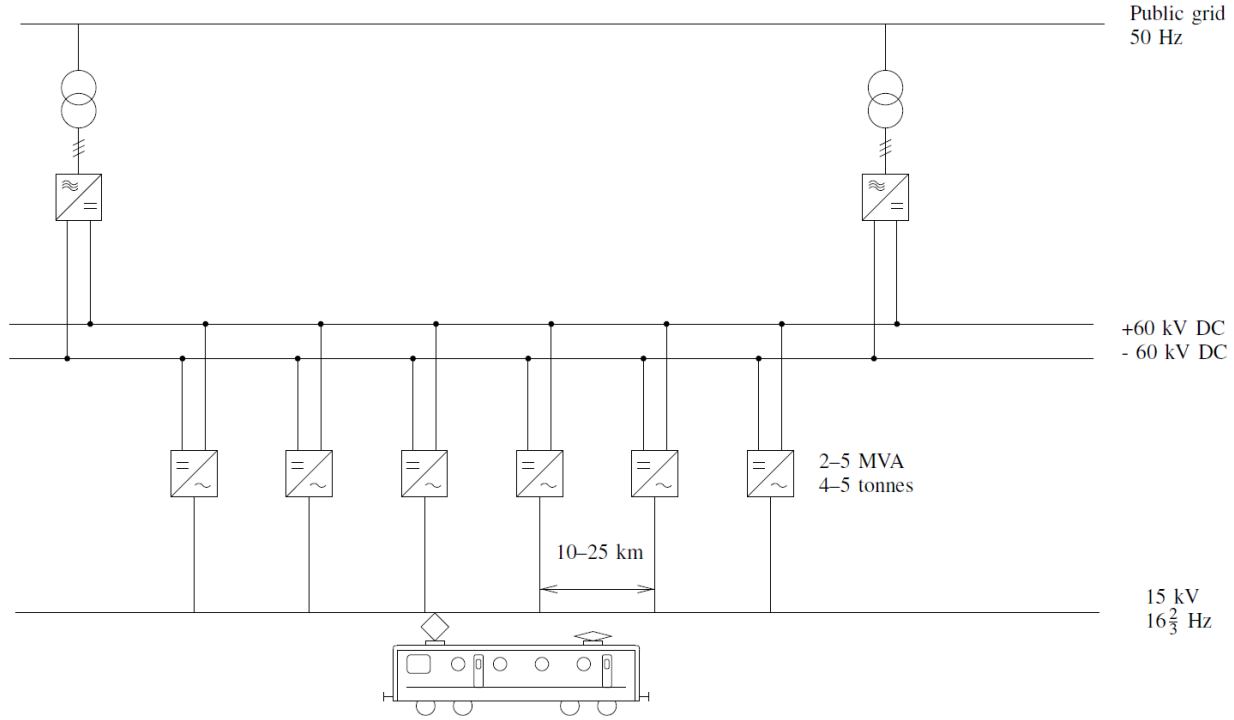
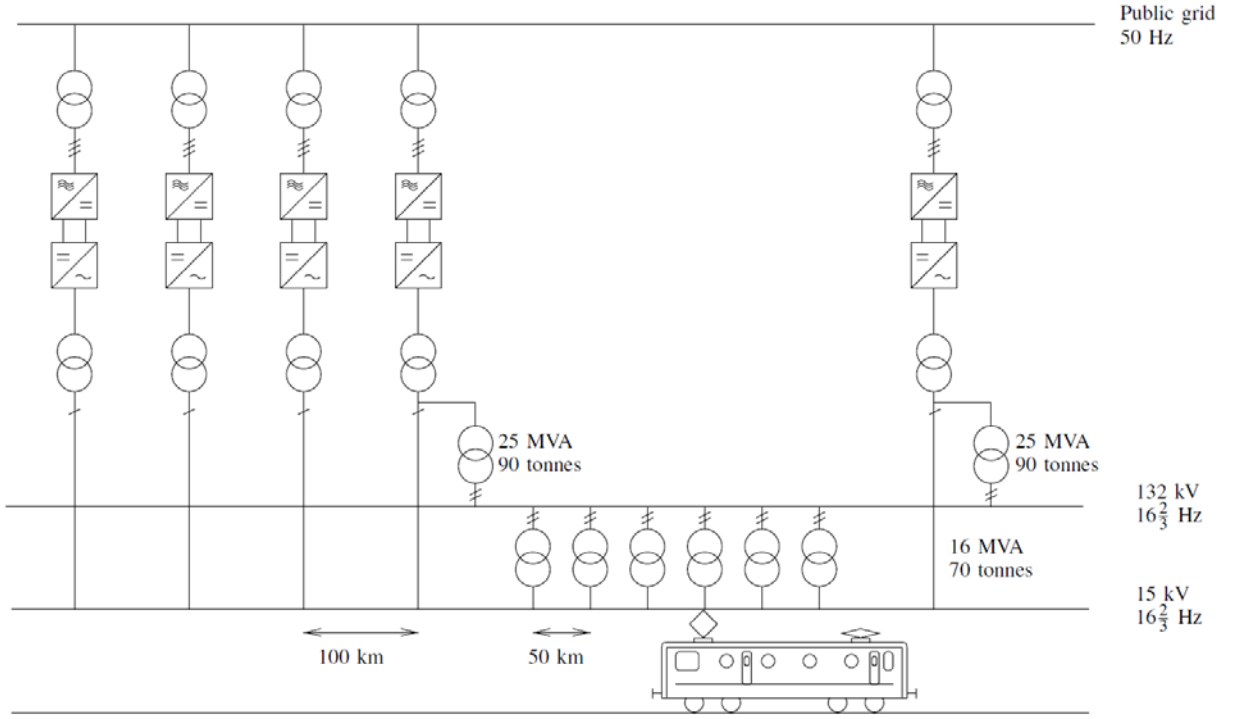
- Comparison of classic and proposed solution





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Brief summary of results in thesis
Operation Part

- Moving loads
  - Train Power Systems Simulator (TPSS)
    - Developed for Licentiate degree
    - Dimensioning studies and eventually investment planning
    - Further developed continuously
    - Studies consecutive time steps of operation
      - Power flows and allowable acceleration determined
      - Whereupon speed and position are computed
  - Fixed node model
    - Presented the idea at COMPRAIL 2012
    - More detailed article on its way
    - Main idea
      - Non-moving loads, power system fixed
      - Train operation optimized over time
      - Optimal charge/discharge policies
      - Optimal driving strategies
      - Allows easier modeling (computer takes care)

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Brief summary of results in thesis
Design Part

- Placement of converters
  - Basic model: number of converters given
  - Focusing on voltage-drop-reduced traffic
  - Presented at ISAP 2009 – DNLP model
  - Reformulated to MINLP – not yet submitted

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Future Work
Being Done

- Converter Usage
  - Quantify results in Masters' Thesis proposal
- Operation Part
  - HVDC and OPF
    - Moving load studies under way
    - Realizable voltage control under way
  - Fixed node model
    - Some improvements done
    - Manage variable speed limits
    - Running resistance of slopes and curves
      - Straightforward to model compared to TPSS
- Design Part
  - Reformulation to MINLP
  - An alternative formulation – only on paper

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Future Work
Elektra Application

- Operation Part
  - HVDC and OPF
    - Faster simplified optimal commitment model
    - Faster OPF, even faster as conical?
  - TPSS: handling meeting/overtaking trains
  - Fixed node model
    - Energy storage
    - Centralized tractive force/effort reductions
    - Write a “TPSS” of it
      - Keep the “fixed-node” simpler programming
      - Remove the time dimension
- Electrical Roads
  - Point out the similarities with railways
  - We have knowledge if industry interested

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Future Work
General Thoughts

- Converter Usage: China? USA (25 Hz)?
- OPF
  - Handle/classify bad/delayed/absent data
  - Power system dynamics and stability
- Design Part
  - Sizing of converters – not only placement!
    - Considering peak power demands
    - Energy – operation cost, like traveling times
    - Economies of scale regarding investments
  - Model improvements
    - Long-term models, i.e. time dimension
    - Uncertainties – prices, loads, lead times
    - Generally – to make the problems computable

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Time for questions

- Please, ask something here and now!
- If you are shy – email me!
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