
AREVA

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WIND FARM

Flexible AC Transmission Systems

WIND ENERGY AND GRID INTEGRATION

Madrid 24-25 January 2006

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SUMMARY

Assumption:

Wind farm is with Fixed Speed Induction Generator (FSIG)

- ***1/ Wind farm operation WITHOUT compensation:***
  - ***Single line diagram / main assumptions***
  - ***Physical aspects - System behaviour,***
  - ***Main factors on system behaviour,***
  - ***Simulations.***
- ***2/ Wind farm operation WITH DYNAMIC compensation:***
  - ***Single line diagram,***
  - ***Design,***
  - ***Simulations,***
- ***3/ Conclusion & cost mitigation***

REQUIREMENTS P.O.12.3

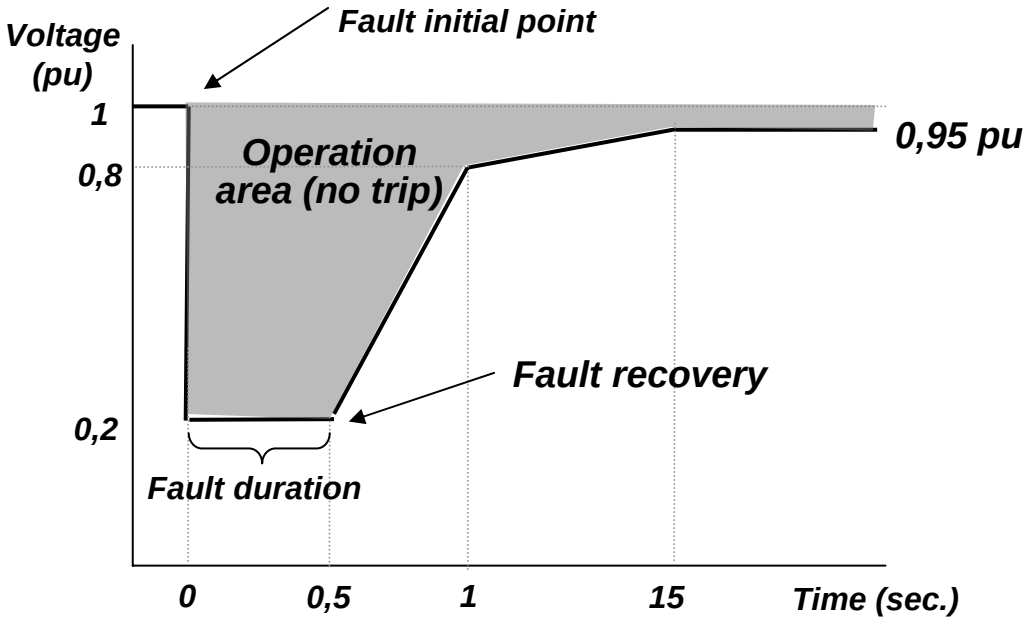


Fig 4.1

RED ELÉCTRICA DE ESPAÑA

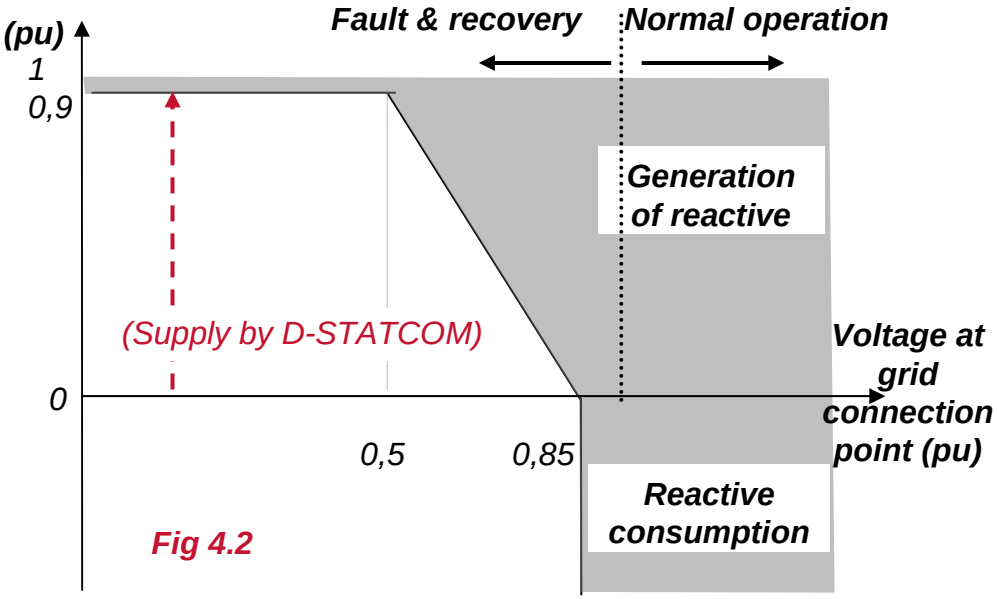
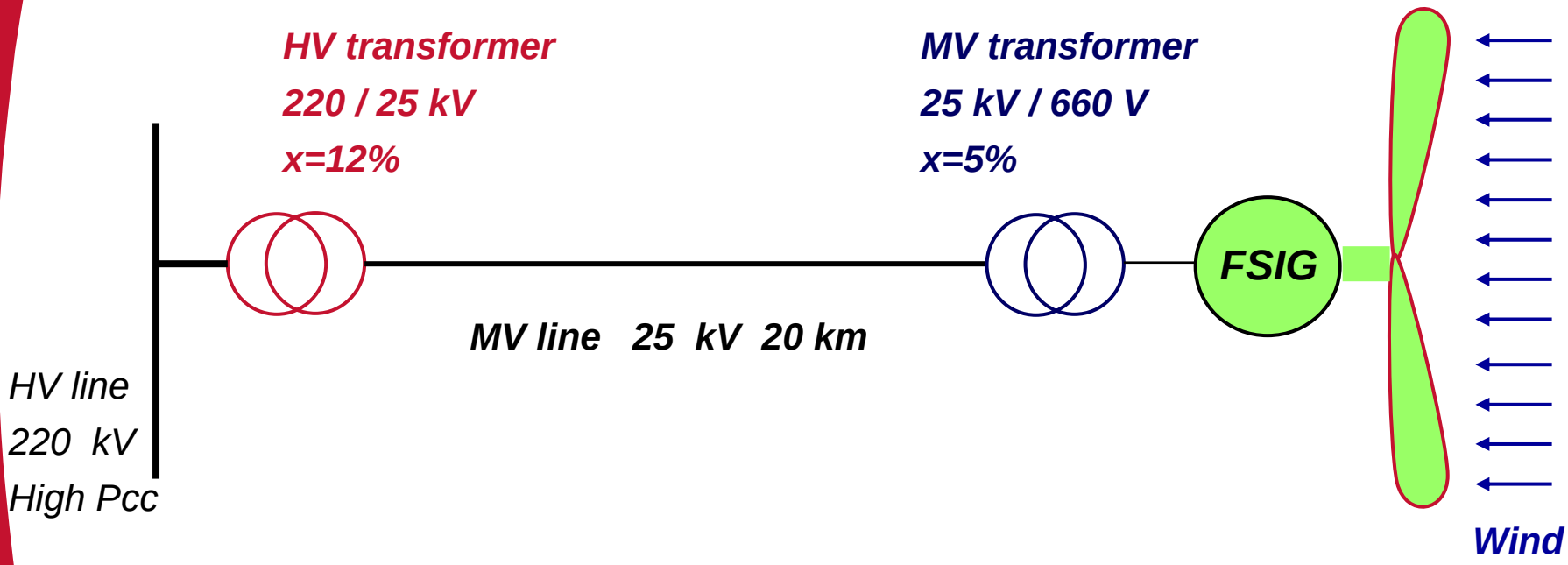


Fig 4.2

RED ELÉCTRICA DE ESPAÑA

1 – WIND FARM OPERATION WITHOUT COMPENSATION

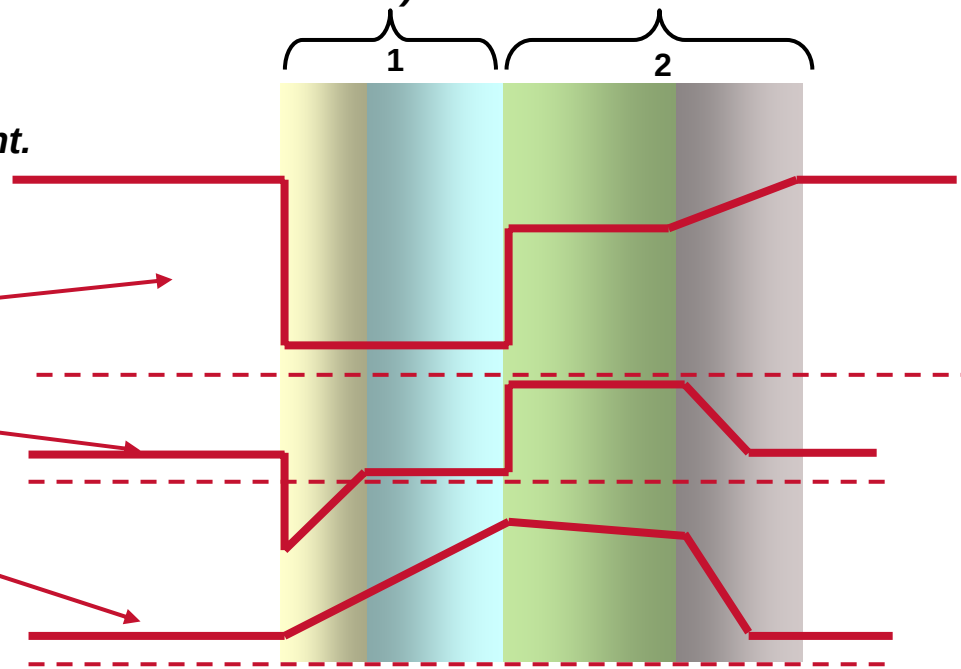
WITHOUT compensation / Single line diagram



- *Assumptions:*
  - *induction, fixed speed generator,*
  - *in principal, network arrangement,*
  - *wind-farm power: from 30 to 50 MVA (approach in pu)*

WITHOUT COMPENSATION PHYSICAL ASPECTS

- *Fault phase (phase 1)*
  - *active energy / mechanical behaviour:*
    - *During Fault Pmeca= Constant,*
    - *Mechanical acceleration according to Inertia,*
    - *Slip of induction generator is increasing,*
    - *Torque at induction generator is decreasing (square of the voltage).*
  - *Reactive current injection*
    - *Generator Voltage > Network Voltage,*
    - *Short time duration ~T's (opened rotor time constant).*
- *Recovery phase (phase 2)*
  - *High amount of reactive current.*

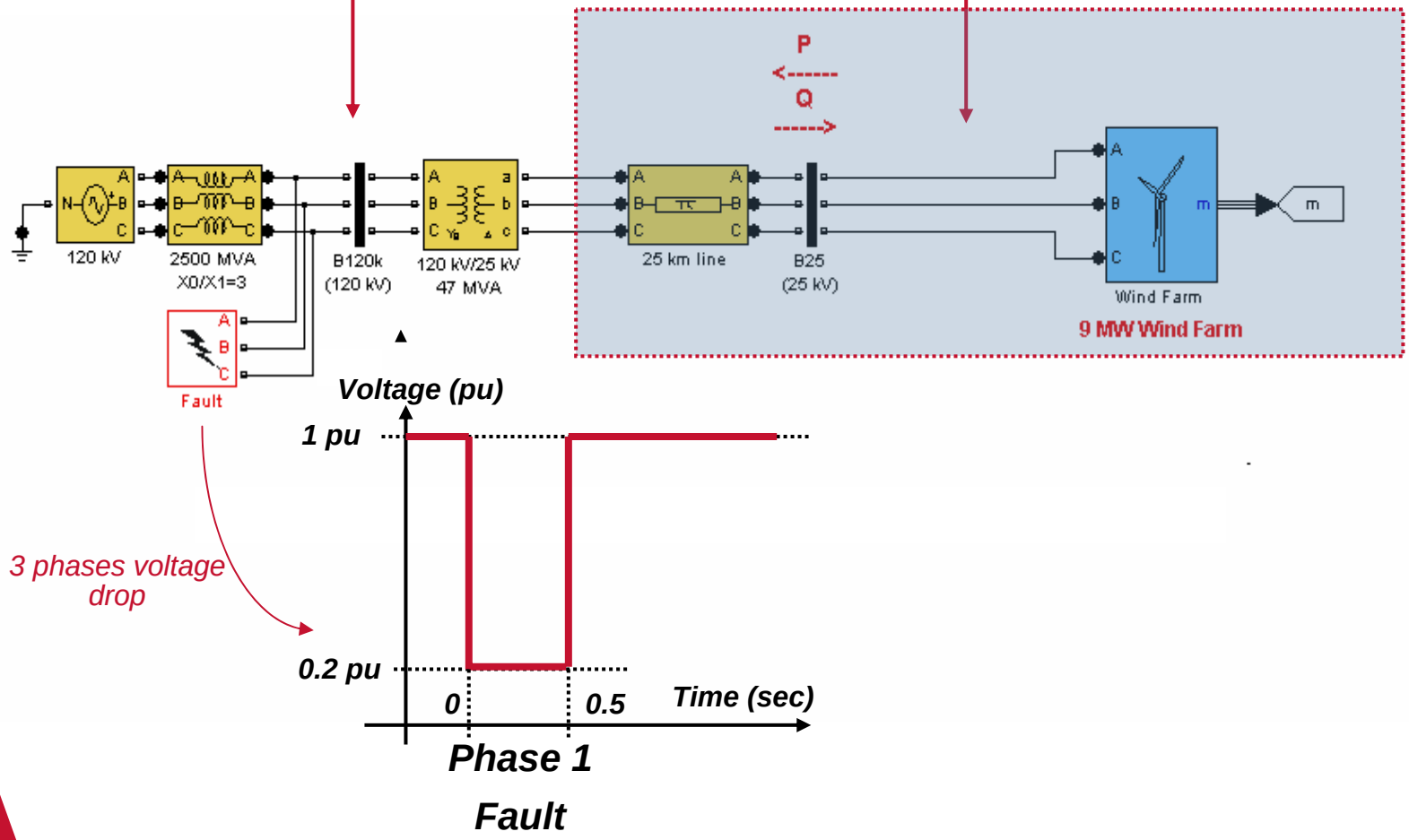


MAIN FACTORS ON SYSTEM BEHAVIOUR

MAIN FACTORS ON SYSTEM BEHAVIOUR
GLOBAL VIEW

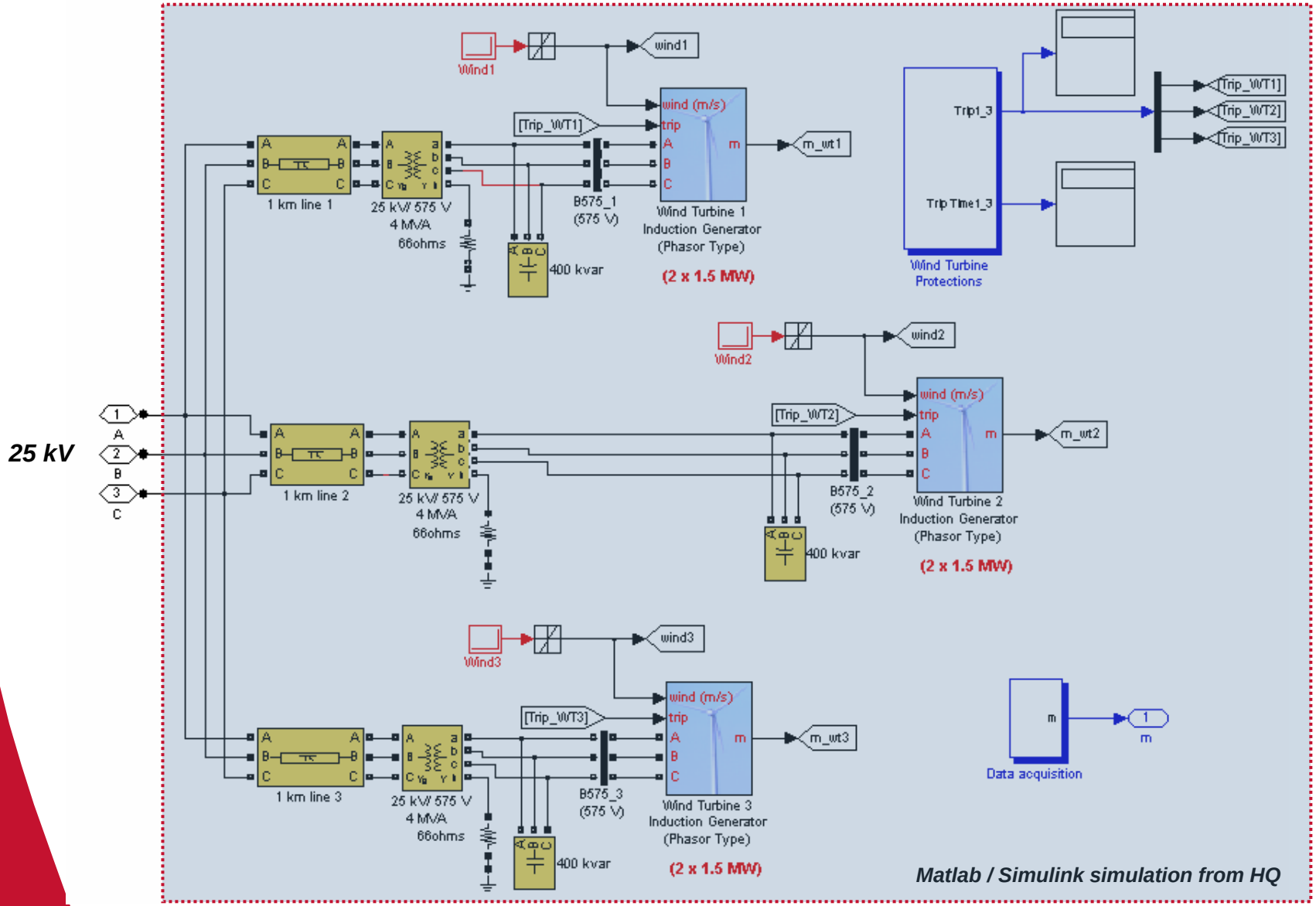
9MW Wind Farm Simulation

- Scc 2500MVA at 120kV Bus
- Scc 55MVA at 25kV Bus



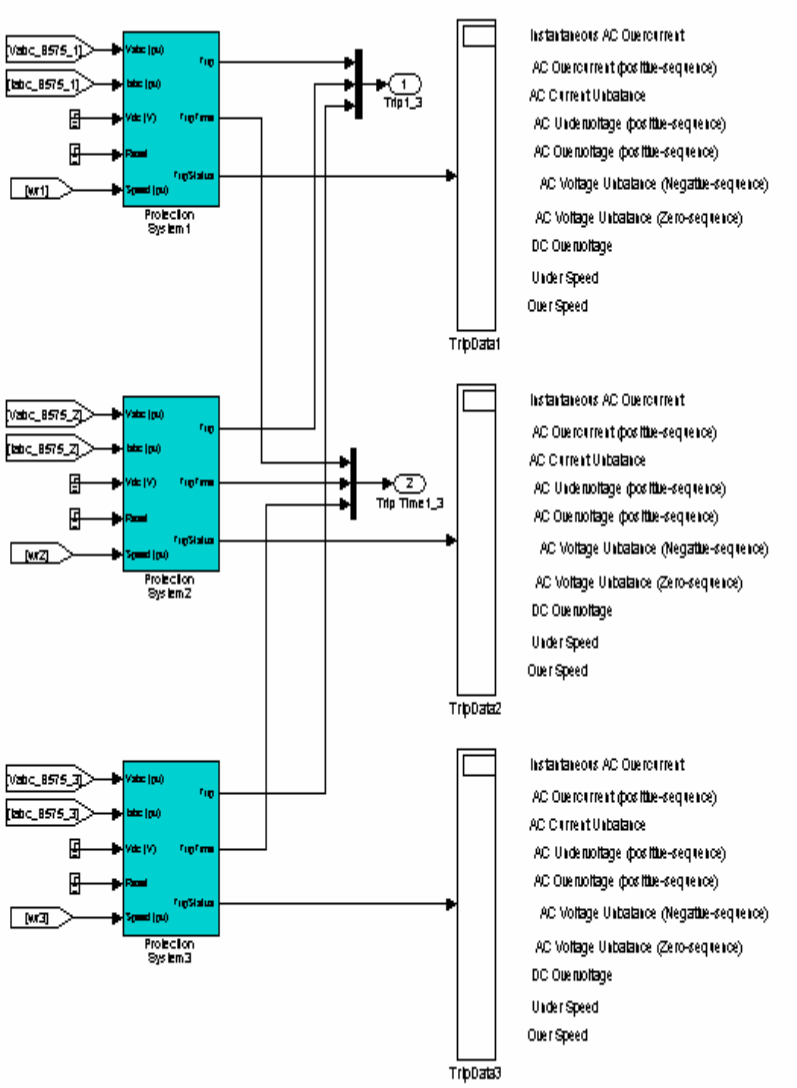
MAIN FACTORS ON SYSTEM BEHAVIOUR

GLOBAL VIEW- SIX WIND TURBINES



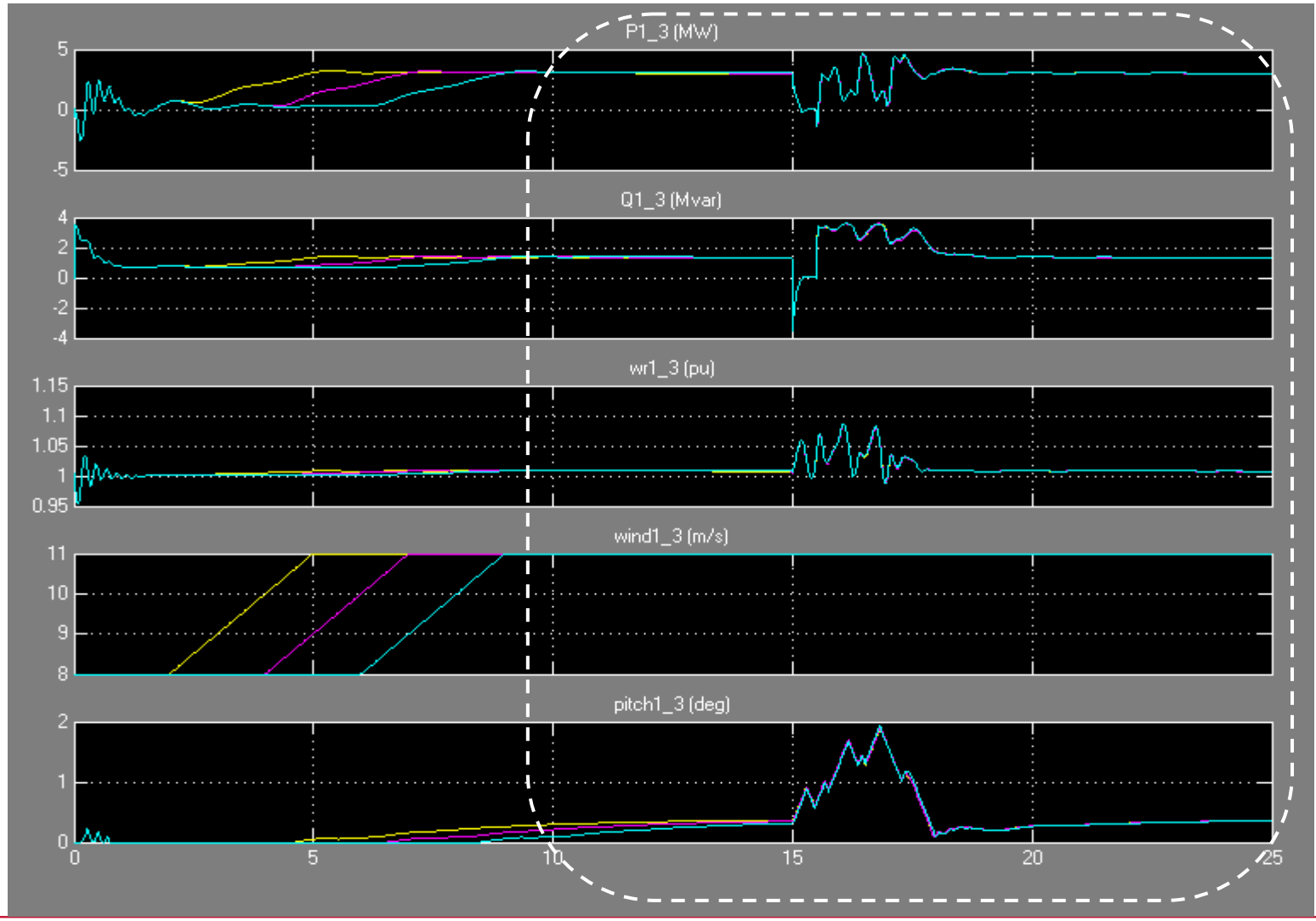
MAIN FACTORS ON SYSTEM BEHAVIOUR SYSTEM PROTECTIONS

- *AC Overcurrent (Inst)*
- *AC overcurrent (positive seq.)*
- *AC current imbalance*
- *AC undervoltage (positive seq.)*
- *AC overvoltage (positive seq.)*
- *AC voltage unbalance (negative seq.)*
- *AC Voltage unbalance (Zero seq.)*
- *Underspeed*
- *Overspeed*



Wind Farm Simulation WITHOUT compensation

- **9MW Wind Farm (With pitch control, pitch rate 2°/s)**
  - **at wind turbine bus**

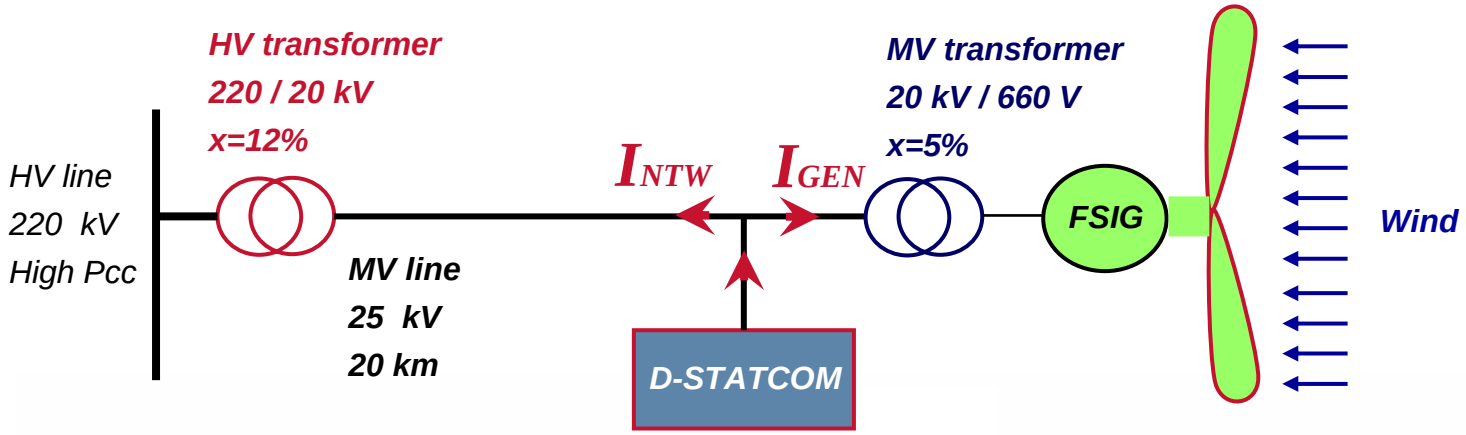


WIND FARM SIMULATION WITHOUT COMPENSATION
PITCH CONTROL - SYNTHESIS

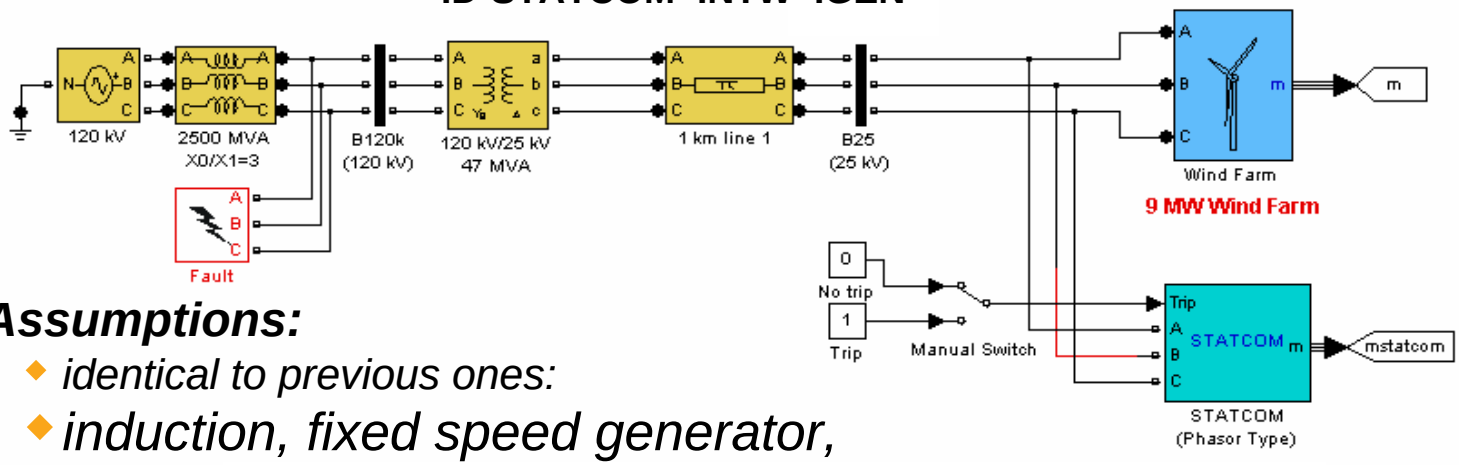
- *9MW Wind Farm (With pitch control, pitch rate 2°/s)*
  - *With taken assumptions*
    - *Fault duration 500ms*
    - *protection levels*
  - *Wind Farm won't trip with the help of pitch control DURING fault recovery*
  - *High reactive power consumption during fault recovery untill pulling in.*
  - *No respect of Fig 4.2 of P.O.12.3*

2 - WINDFARM OPERATION WITH COMPENSATION

WITH COMPENSATION - SINGLE LINE DIAGRAM



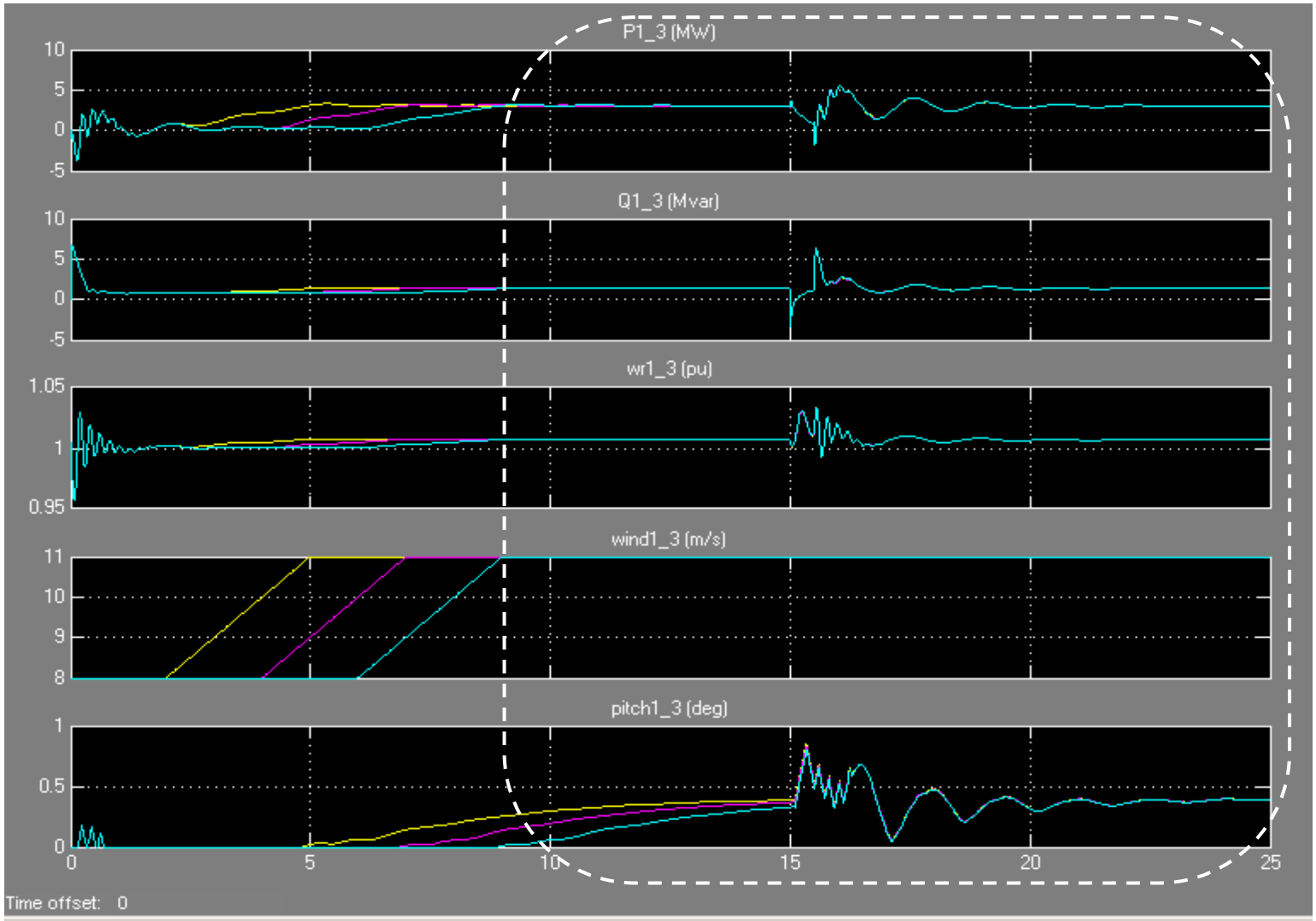
ID-STATCOM=INTW+IGEN



- ***Assumptions:***
  - *identical to previous ones:*
  - *induction, fixed speed generator,*
    - *in principal, network arrangement,*
    - *wind-farm power: from 30 to 50 MVA (approach in pu),*
  - *in addition, D-STATCOM for compensation:*
    - *VSC equipment,*
    - *installed power in pu.*

Wind Farm Simulation With D-STATCOM

- **9MW Wind Farm (with pitch control pitch rate 2°/s)**
  - **at Wind turbine (D-STATCOM 19.5MVA ~2.16 p.u.)**



WIND FARM SIMULATION WITH D-STATCOM

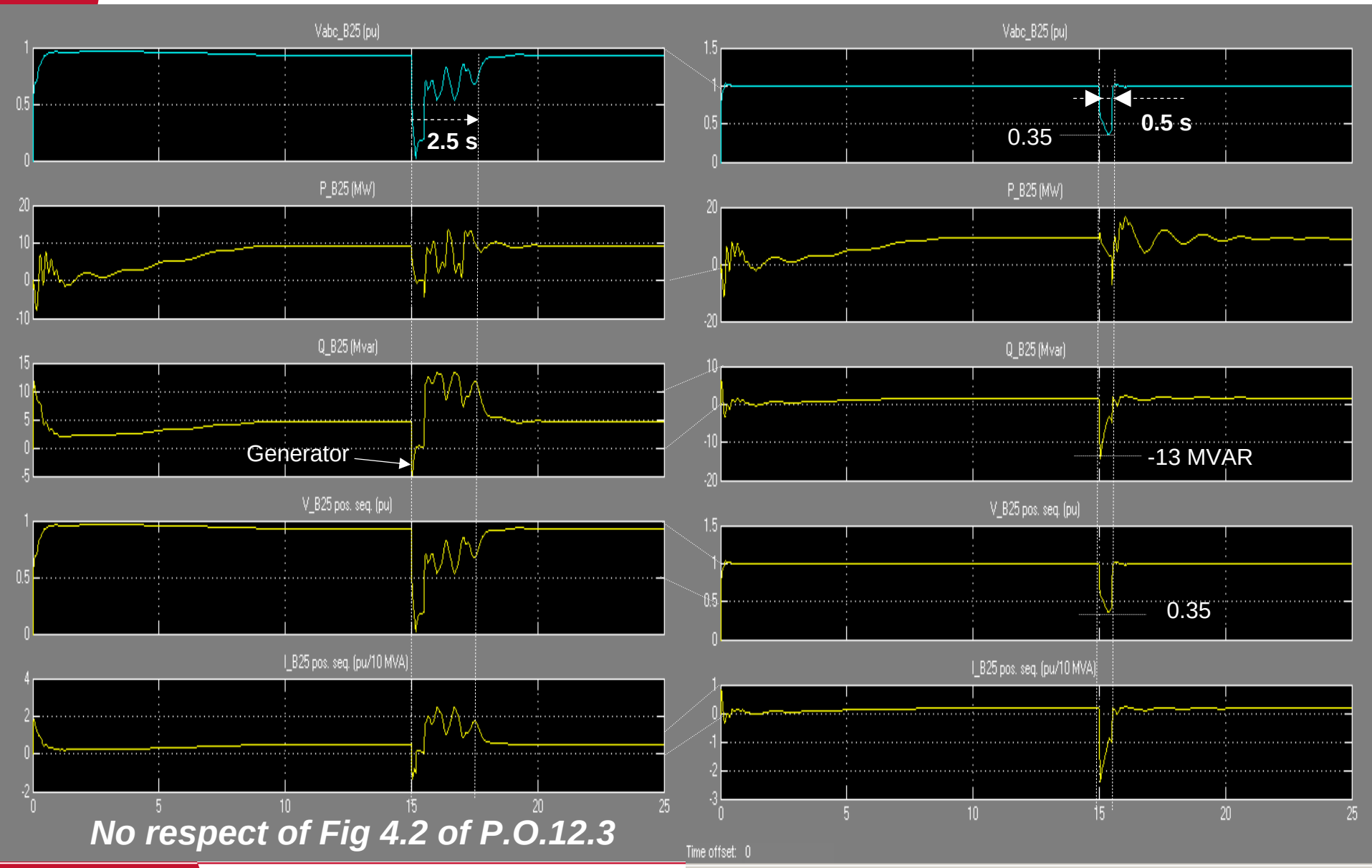
- ***9MW Wind Farm (with pitch control pitch rate 2°/s)***
  - ***With taken assumptions***
  - ***With the help of 2.16 p.u of D-STATCOM,***
  - ***No reactive power consumption during fault and after recovery***
  - ***Respect of 1 p.u current injection at Pcc during fault***

3 - CONCLUSION & COST MITIGATION

WITHOUT / WITH D-STATCOM – 9 MW WIND FARM

Without dynamic compensation

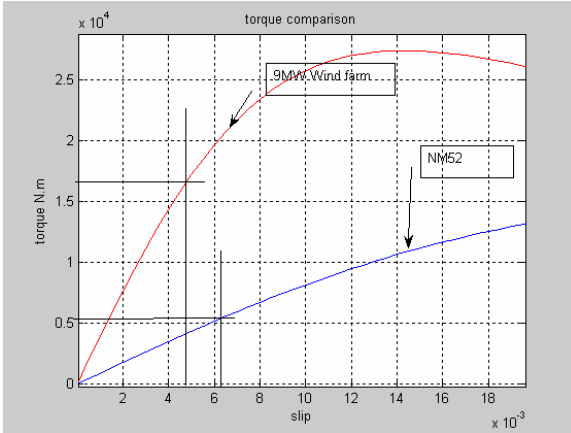
With 19.5 MVAR D-STATCOM



No respect of Fig 4.2 of P.O.12.3

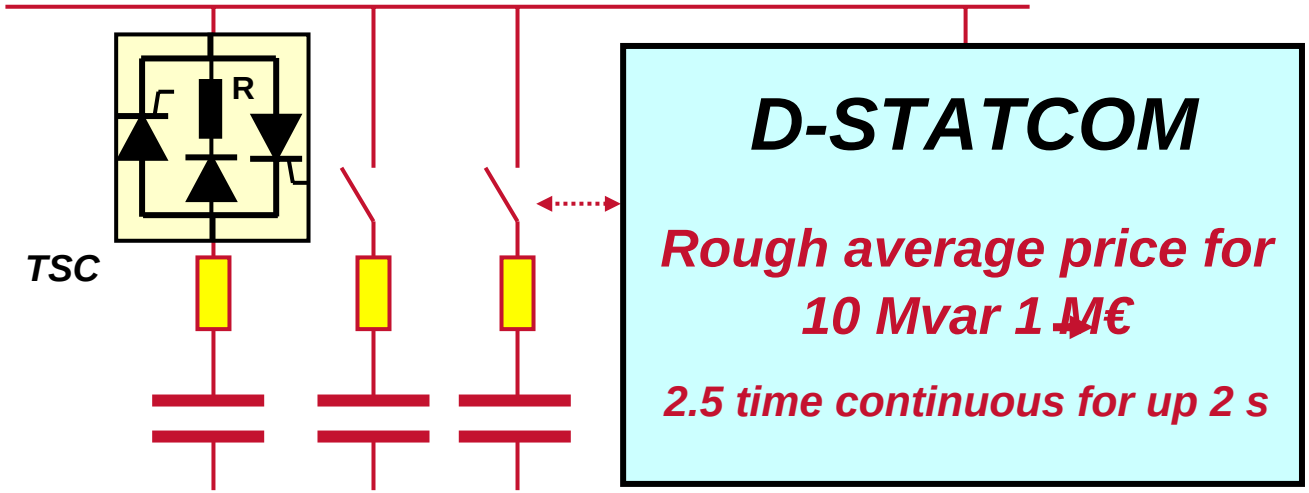
WIND FARM WITH COMPENSATION CONCLUSION

- **ASSUMPTION: Fixed Speed Induction generator case**
- **MAIN CONCLUSION:**
  - Case by Case study
    - Network data
      - Impedance of Connecting transformer and line
    - Wind turbine data:
      - type of active power and speed control
      - design for protection levels
      - Inertia
    - Generator data
      - Curve Torque/slip
      - ratio sk/sn and Tek/Ten
  - Huge amount of reactive power needed during faults …

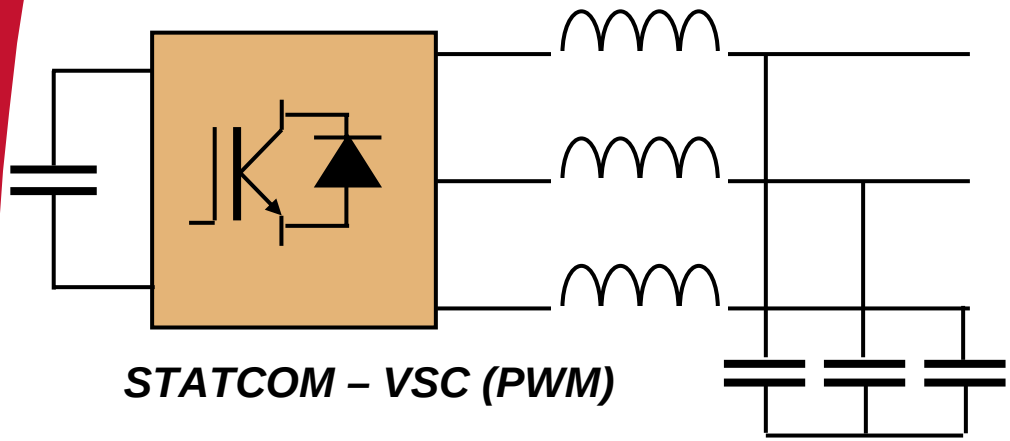


WIND FARM WITH COMPENSATION COST MITIGATION

- ***ASSUMPTION: Fixed Speed Induction generator case***
- ***Costs mitigation***
  - ***Power electronics VSC has a typical overload capability of 2 - 2.3***
  - ***Keeping our case study: SVS size = 1.15 p.u with x 2 overload capability***
  - ***To reduce costs:***
    - ***Splitting SVS in D-STATCOM and MSC***
    - ***Splitting SVS in D-STATCOM and TSC.***
    - ***.../...***



10 Mvar peak ➡1 M€ …. EXPENSIVE….



STATCOM – VSC (PWM)

BUT … In normal operation the STATCOM …

- May control cos ϕ
- May eliminate the negative sequence.
- Can be a active filter
- Can be a dynamic damper.

Just for cos ϕ and negative sequence, the simple SVC is a good solution.