

# Phasor Measurements Recording South Sweden – Eastern Denmark April 2002

Daniel Karlsson, Sture Lindahl  
ABB, Sweden  
daniel.h.karlsson@se.abb.com

Tomas Johannesson  
Sydkraft Elnät Syd  
Sweden

**Background:** The connection between southern Sweden and eastern Denmark comprises a double 400 kV line and a double 130 kV line. Both the 400 kV lines were taken out of service for 2 weeks in the beginning of April 2002, in order to connect a new substation (Gørløse) on the Danish side. During this outage period the power transfer was limited to 100 MW in each direction (compared to 1300 MW (to Sweden) and 1600 MW (to Denmark) at normal conditions). To document the properties of the ABB RES 521 PMU beta version, and to capture the power oscillations, in case of a disturbance, two PMUs were installed in Söderåsen (on the Swedish side) and Asnæsverket (on the Danish side). The transmission grid for eastern Denmark is shown in Figure 1.

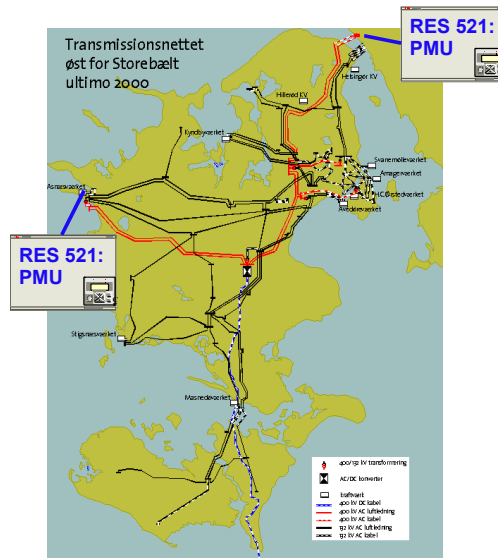


Figure 1. The eastern Danish power system, equipped with PMUs.

**Field tests:** The PMUs were installed and commissioned totally independent of each other and the data recorded were stored in a PC standing right next to the PMU, in the substation. When the recording period was over, the PMUs were decommissioned and the data from the two substations were aligned, according to the common time reference supplied by the GPS system. The recording was successful – no interruption or missed data was observed. The table in Appendix 1 shows the quantities recorded. All voltages and currents recorded are positive sequence quantities.

**Results:** Since no “especially interesting event occurred”, the reconnection of the 400 kV system is shown in a few diagrams, in Appendix 2. The diagrams show the data as it appears from the log-files, no filtering has been done. It is impressive to see the high resolution and the distinct signals. The magnitude of the oscillations is limited as well as the duration. The frequency of the oscillation is around 0.7 Hz. It is especially interesting to compare the voltage phase-angle between Söderåsen and Asnæsverket, with the active power on the 130 kV connection. The correlation is, as expected, obvious.

**Conclusions:** The recordings are very promising. The present recording shows that the ABB RES 521 PMU beta version provides high resolution, noise free signals suitable as inputs for power oscillation damping equipment.

**Future work:** The recording technology has now come to a secure and reliable stage. The main development has now to be on applications, to really make benefit of the high precision time synchronized measurements. Applications on damping, state estimation, out-of-step conditions, etc., are just waiting to be designed and implemented. The economic potential of increased utilization of the power system infrastructure based on improved measurement techniques and advanced control seems to be well worth further studies.

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### Power System Quantities Recorded by the PMUs in Söderåsen and Asnæsverket

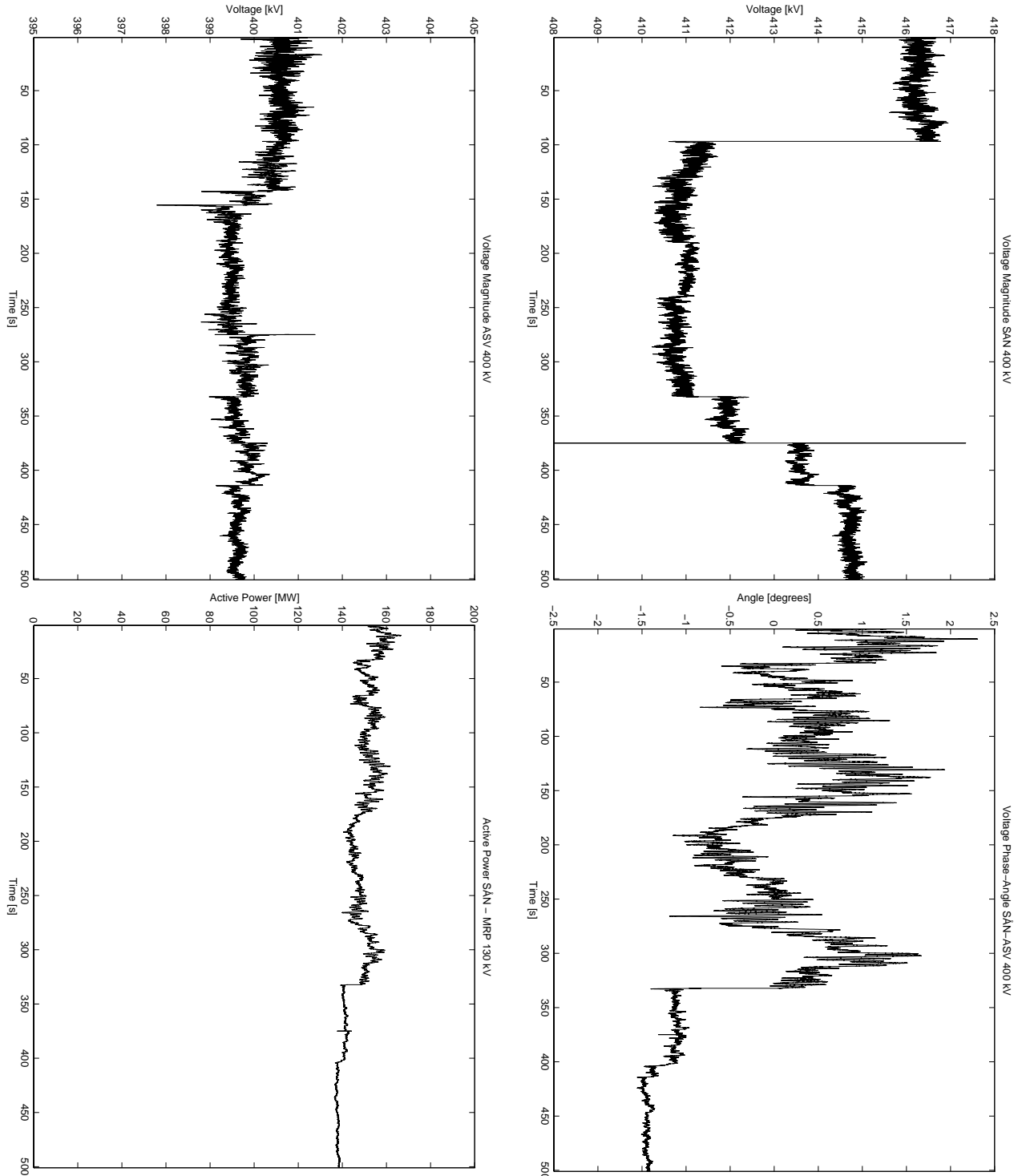
Voltage Söderåsen 400 kV real part, positive sequence, [kV]  
Voltage Söderåsen 400 kV imaginary part, positive sequence, [kV]  
Voltage Söderåsen 130 kV real part, positive sequence, [kV]  
Voltage Söderåsen 130 kV imaginary part, positive sequence, [kV]  
Current Söderåsen 400 kV to Barsebäck, real part, positive sequence, [A]  
Current Söderåsen 400 kV to Barsebäck, imaginary part, positive sequence, [A]  
Current Söderåsen 400 kV to Transformer 130 kV, real part, positive sequence, [A]  
Current Söderåsen 400 kV to Transformer 130 kV, imaginary part, positive sequence, [A]  
Current Söderåsen 130 kV to Mörrarp I, real part, positive sequence, [A]  
Current Söderåsen 130 kV to Mörrarp I, imaginary part, positive sequence, [A]  
Current Söderåsen 130 kV to Mörrarp II, real part, positive sequence, [A]  
Current Söderåsen 130 kV to Mörrarp II, imaginary part, positive sequence, [A]  
Frequency (fundamental) Söderåsen 400 kV [Hz]  
Rate of change of fundamental frequency Söderåsen 400 kV [Hz/s]

Voltage Asnæsverket 400 kV real part, positive sequence, [kV]  
Voltage Asnæsverket 400 kV imaginary part, positive sequence, [kV]  
Current Asnæsverket 400 kV to Transformer 130 kV, real part, positive sequence, [A]  
Current Asnæsverket 400 kV to Transformer 130 kV, imaginary part, positive sequence, [A]  
Current Asnæsverket 400 kV to Bjeversgaard I, real part, positive sequence, [A]  
Current Asnæsverket 400 kV to Bjeversgaard I, imaginary part, positive sequence, [A]  
Current Asnæsverket 400 kV to Bjeversgaard II, real part, positive sequence, [A]  
Current Asnæsverket 400 kV to Bjeversgaard II, imaginary part, positive sequence, [A]  
Frequency (fundamental) Asnæsverket 400 kV [Hz]  
Rate of change of fundamental frequency Asnæsverket 400 kV [Hz/s]

## Recordings from the PMUs in Söderåsen and Asnæsverket – 2002-04-19

The diagrams show the reconnection of the 400 kV connection, during a 500 second period.

- **Voltage magnitude Söderåsen 400 kV:** The first step-change in voltage (~90 s) comes from the connection of a 150 Mvar shunt reactor in Söderåsen. The second step-change (~330 s) comes from the connection of the first 400 kV line. Next step-change (~370 s) shows a transient, and comes from the energizing of the second 400 kV line from the Swedish side. The transient comes from the line capacitance in combination with the fixed line reactor. The final step-change comes from the connection of the second 400 kV line on the Danish side.
- **Voltage magnitude Asnæsverket 400 kV:** The voltage level is rather stable, due to the voltage control in the power station.
- **Voltage phase-angle:** The diagram shows the phase angle between the 400 kV voltage in Söderåsen and in Asnæsverket. Note especially the scale resolution! It is obvious that after the connection of the first 400 kV line the phase angle is much more stable. It is also possible to see a further stabiliztion after the connection of the second 400 kV line.
- **Active power from Söderåsen to Mörarp 130 kV:** If something happens on the Danish side, this was the power flow that would be affected on the Swedish side, during the outage.



## Appendix 2 2(2)

### Recordings from the PMUs in Söderåsen and Asnæsverket – 2002-04-19

The diagrams show the reconnection of the 400 kV connection, during a 10 second period, just around the connection of the first 400 kV line.

- **Voltage magnitude Söderåsen 400 kV:** A small voltage increase can be observed.
- **Voltage magnitude Asnæsverket 400 kV:** Small changes only.
- **Voltage phase-angle:** A distinct phase shift and then a small well damped oscillation can be observed.
- **Active power from Söderåsen to Mörarp 130 kV:** The change in power flow corresponds to the change in phase angle.

