21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

(Insert paper #)

CIGRÉ Canada
Conference on Power Systems
Halifax, September 6- 8, 2011

Quantifying the limits of weather based dynamic line rating methods

PETER SCHELL[1], HUU MINH NGUYEN[2], JEAN-LOUIS LILIEN[2]
Ampacimon SA[1](BE), University of Liège[2](BE)

SUMMARY

Dynamic Line Rating (DLR) is a subject that has been around for more then a decade. During this time many methods to determine a DLR or Real Time Thermal Rating (RTTR) have been developed and tested. One of the key issues to solve the thermal equations is knowing weather data with enough accuracy either as observations or forecast. This paper will thus focus on the influence weather observations and forecasts and their inaccuracy have on the real-time or predicted DLR. The paper will also highlight how it is possible to deal with this issue both for real time calculations and predictions of line ampacity.

Weather data measurements are by definition geographic point measurements. This in itself is a major issue as the influence on the total thermal equilibrium of an overhead line and therefore its thermal rating depends on the global situation for a complete span first (where local effects may affect local wind speed) , then every sections, and finally the full line between the two substations and their corresponding switch bays (with their apparatuses). This is particularly relevant in respect to wind speed and direction, which can vary very significantly from one point to the next.

As wind speed and direction are the most influential parameters on the thermal rating of the line this inaccuracy of the data over the total span and section has a major influence on the outcome and can generate a significant error margin on the calculated real-time and predicted thermal rating.
There is however a solution to this problem by determining the equivalent wind not by direct measurement but by the effect it has on the line clearances. Instead of using the wind as input into the thermal equilibrium equation of the line it becomes an output once the current through the line is known and the sag resulting from this current and the prevailing weather conditions is accurately measured. Determining the "effective windspeed", i.e. the equivalent windspeed perpendicular to the conductor axis, which justifies the actual sag observation, in this way, allows us to include all local variations and to calculate the maximum current-carrying capacity (the DLR) using the wind data as it is sensed by the conductor as a whole. Our measurements have shown that on average the ampacity calculated in this way represents an improvement, compared to the measured wind data approach of about 10%. The ampacity values of the measured wind data approach vary between half and nearly double the value of the ampacities based on actual sag measurements.

peter.schell@ampacimon.com

What is true for wind measurements is also true for weather forecasts. Comparing the ampacity calculated using forecasted weather data (even very high resolution optimized weather forecast) show significant differences compared to the measured ampacity using the method described above. More then half the time (50-55%) the ampacity based on the predicted weather data is more then 10% off and on average the error is between 12 and 14 % respectively for winter and summer. It is plain to see that a better solution must be found to obtain usable ampacity forecasts if the aim is to use these values as input for the day-ahead loadflow calculations of the TSO's. This is one of the aims of the EU funded Twenties project to which we are actively participating. Using the historical behavior of the line as measured by the sag measurement units described above and coupling this data with weather data measurements and the most accurate weather forecast available, and using advanced machine learning techniques, we believe we can achieve a significant improvement in the reliability and precision of the calculated ampacity predictions, to the point where these day-ahead predictions can be used in full confidence by the TSO's together with short-term (4 hours) predictions and real-time sag measurements to significantly increase the system capacities of their networks.

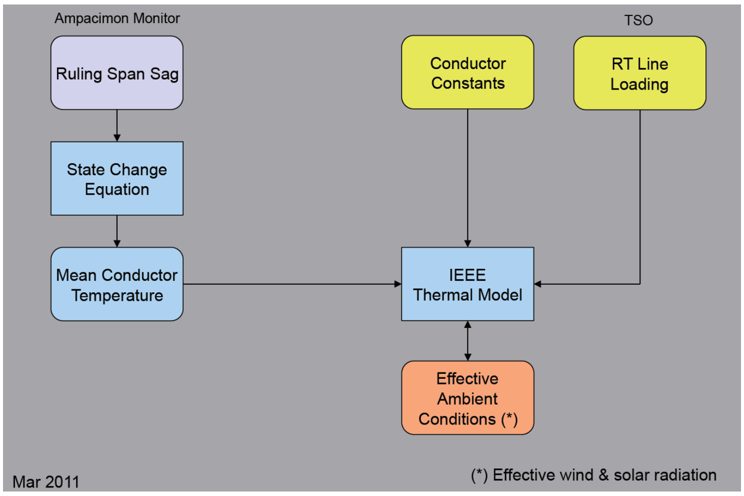
KEYWORDS

Ampacity prediction, DLR (Dynamic Line Rating), Overhead Line Monitoring, RTTR (Real Time Thermal Rating),

peter.schell@ampacimon.com

1. INTRODUCTION

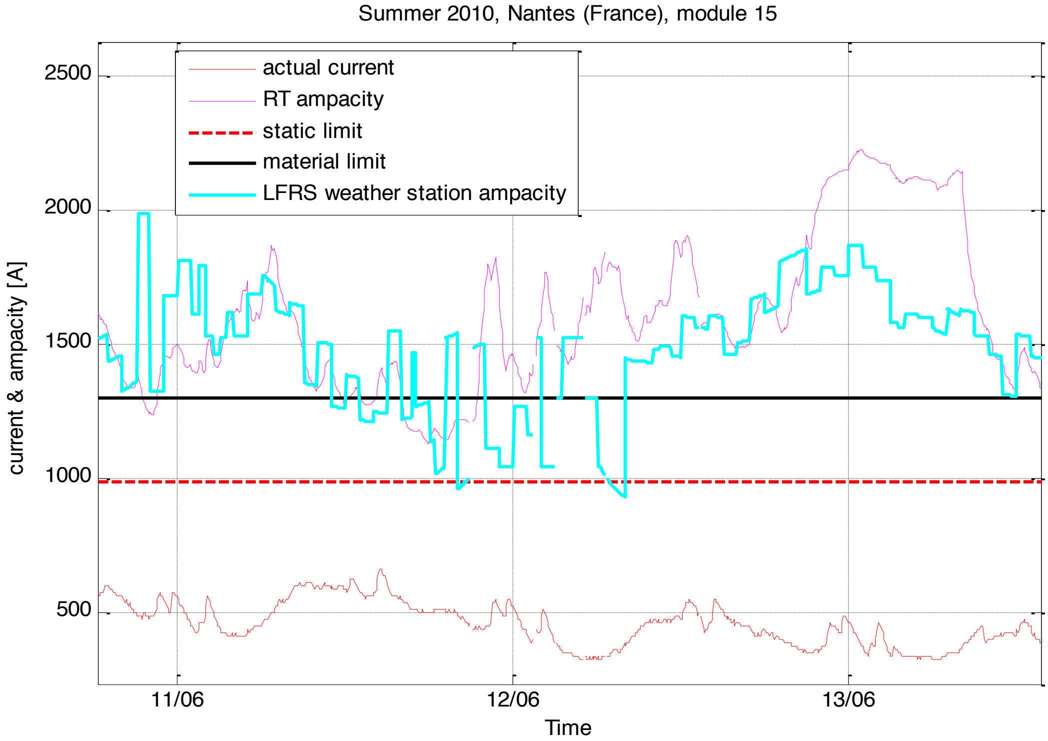
Wind is the dominant factor that influences the DLR of an overhead line [1]. It is therefore natural that the idea to measure or forecast the wind (and ambient air temperature and radiation) and use this data to calculate the DLR of the line is one of the first that comes to mind. The issue with this method is that weather parameters and wind in particular vary significantly with space. Due to the local topology, the turbulence, the boundary layer effect, thermal effects, clouds … the wind speed and direction will vary significantly over the distance of a span and section. As it is the global wind as sensed by the conductor that determines its thermal equilibrium, point measurements of the weather and in particular the wind variables even taken in close proximity to the line remain inaccurate. Only the ambient air temperature is generally sufficiently homogenous to allow a point measurement to be meaningful for a whole span or section. In the next sections we will quantify the error by comparing ampacities, calculated with the measured or forecasted weather variables as input, to the ampacities calculated using an “on line” sag measurement device [2][3], where the effective wind is deduced from the thermal equilibrium equation using the current, the sag (via the state equation linking sag to the average conductor temperature [4][5]) and the measured ambient air temperature as inputs.[6]



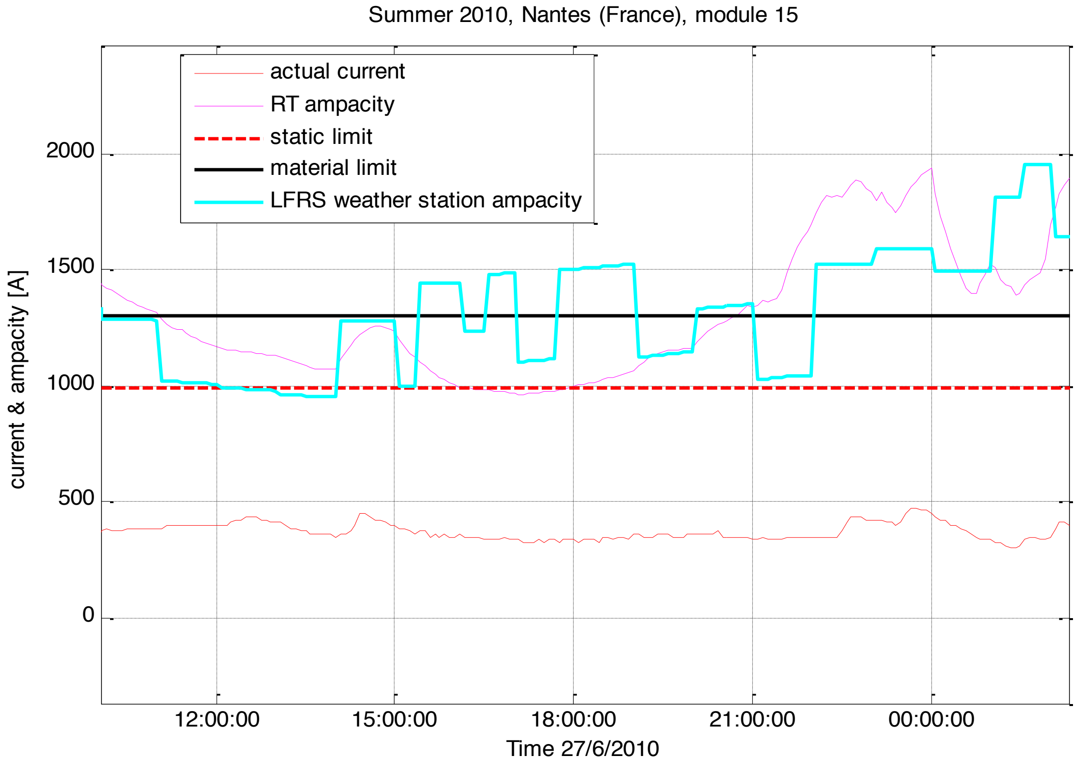
This comparison is done based on one year of data collected near Nantes in France on the RTE Network (see picture) and weather measurements from a Méteo France weather station a few kilometers away from the line.

2. REAL TIME CALCULATIONS

The figure below shows a 3 day period with substantial differences between the ampacity based on the weather station data in turquoise and the ampacity based on the sag measurements (RT ampacity in purple in the graph). During this 3 day period the weather data ampacity is sometimes significantly too low as on the 13th but also sometimes too high as on the 11th.

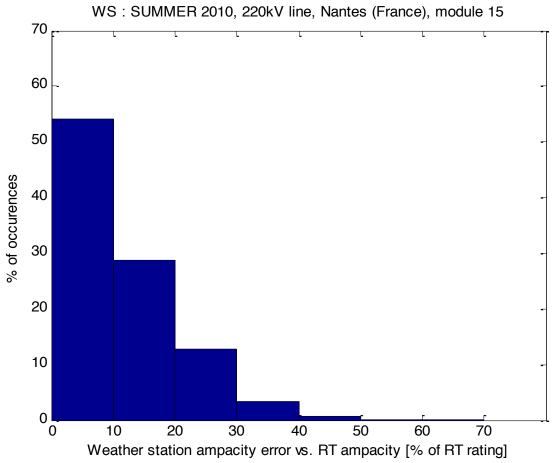


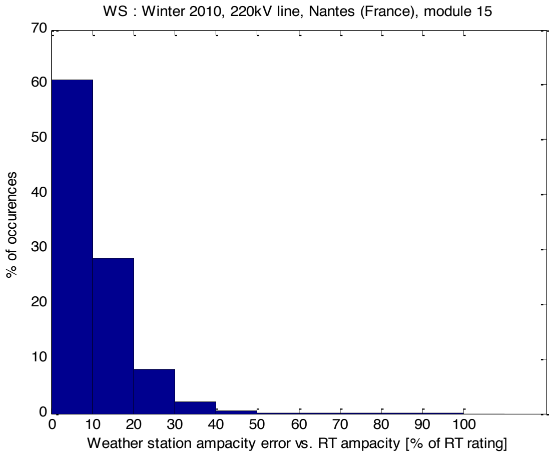
If we zoom in and look at half a day as shown in the graph below, then we see periods of several hours where the weather data ampacity is significantly too high. Operating the line based on the weather data for this day would have been unsafe between 15h and 19h!



On average there is a 10% error in winter and an 11% error in summer of weather-data-based ampacity with respect to the sag-based ampacity. The maximum relative error was 95% in winter and 61% in summer. The figures below show the error distribution. The figures further highlight that the weather-data-based values are more then 10% off 40-45% of the time.

By the way the data also shows that on average over the year, the DLR is 160% above the seasonal ratings currently used for this coastal region.

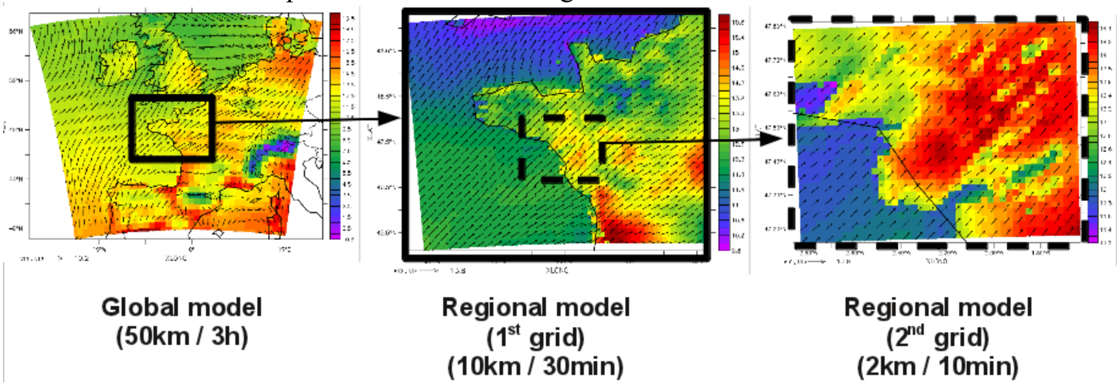




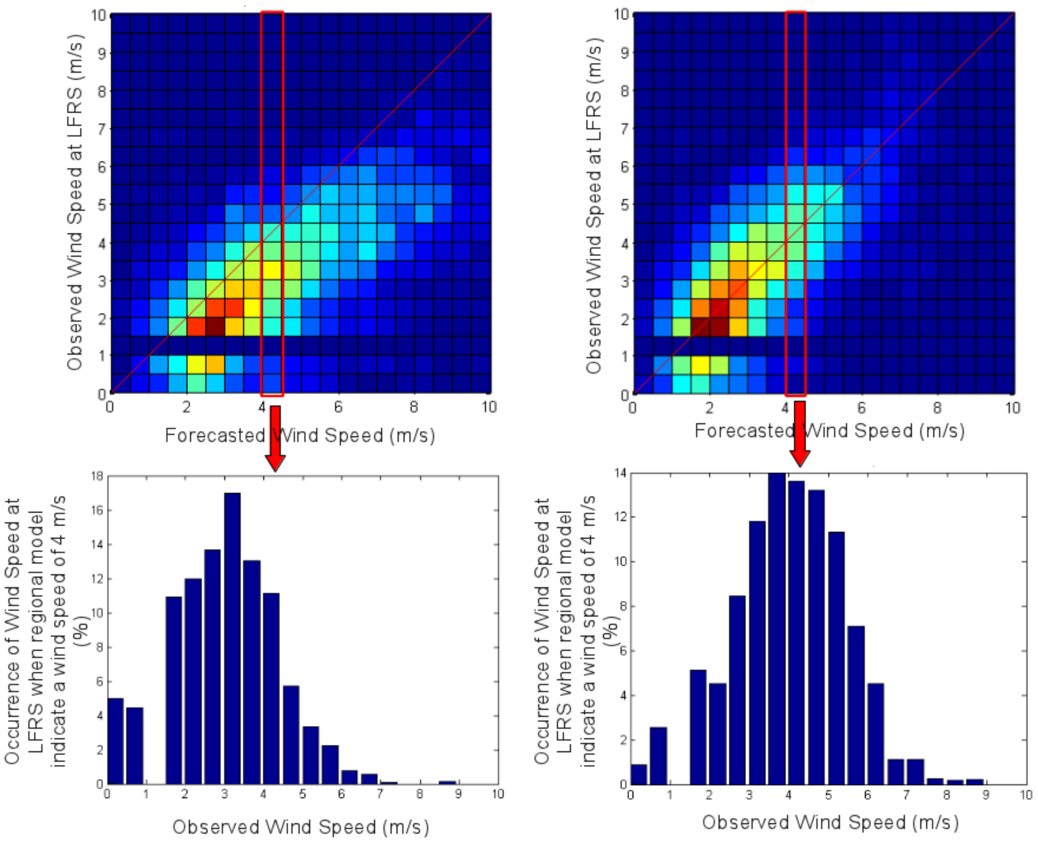
3. PREDICTIONS

As part of the Twenties [7] research project, high resolution weather forecasts have been computed by the Topoclimatology lab of the University of Liège.

The selected weather forecasting model is a special version of the regional climate model WRF opened worldwide to the scientific community. This model physically downscales the coarse outputs of the global model GFS to obtain finer outputs over the studied region.

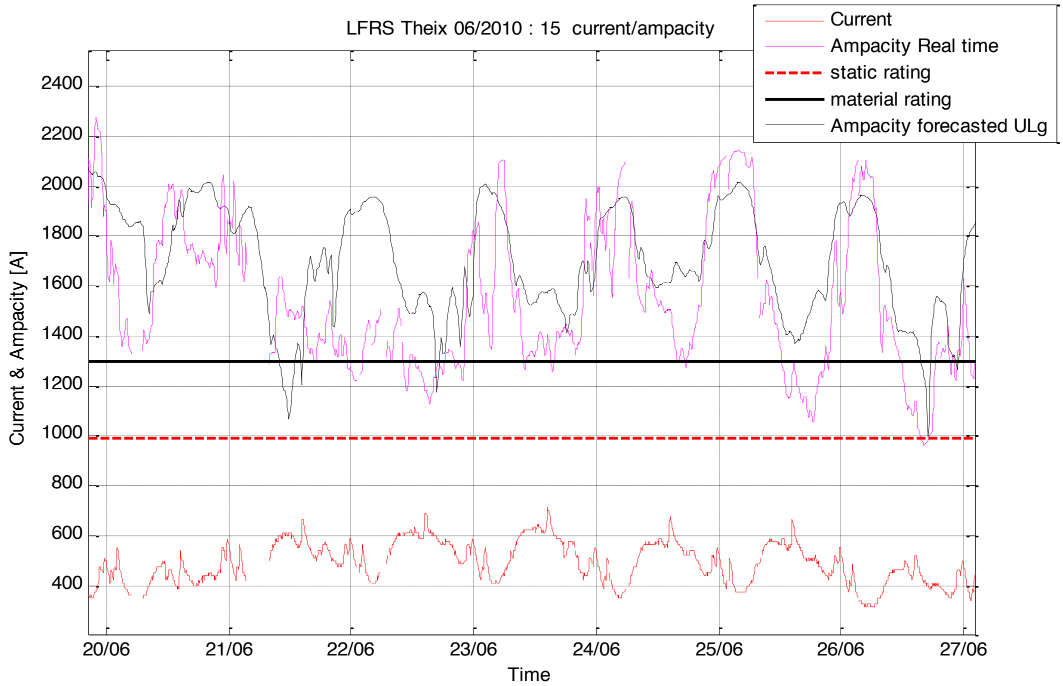


The model was then further improved by comparing its result with the observations of the LFRS weather station. The outputs of the tuned model where used to calculate the ampacity.

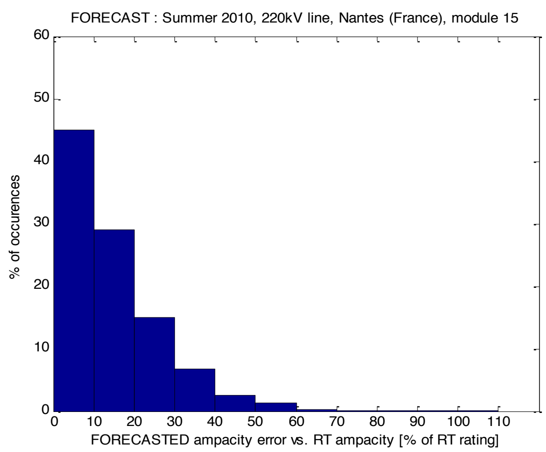


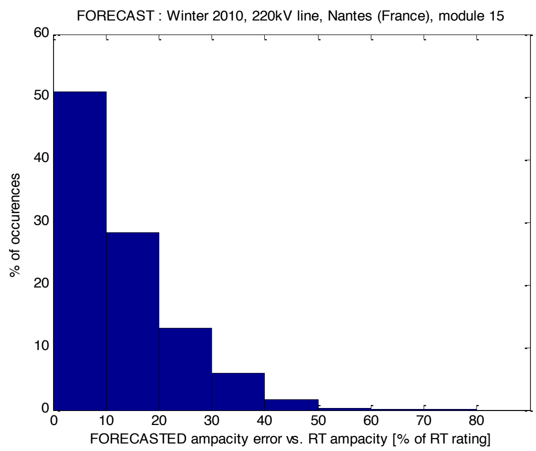
Comparison of the observed wind speed and the forecasted wind speed in the no-fitted version (left side) and in the fitted version (right side)

The figure below shows a comparison of the ampacity computed in real time and the ampacity forecasted by weather forecast provided by ULg Topoclimatology lab, during one week of June 2010.
These results clearly show a good general consistency between these two curves (Pearson correlation coefficient for the year : r = 0.75). However, large discrepancies can be highlighted for several consecutive hours (e.g. 22nd Jun.). Moreover, this error can be critical for the TSO when forecasted rating overestimates actual rating near the static rating value (e.g. 26th Jun.).



Overall, the ampacity based on the high-resolution tuned weather forecast achieves comparable but slightly weaker results to the ampacity based on the observations, which is remarkable. The mean error is slightly higher at 12-14% (winter-summer), the maximum errors are similar and 50-55% of the time the ampacity is more then 10% off.





This is clearly not good enough to be used operationally. Using the historical behavior of the line as measured by the sag measurement units described above, and coupling this data with weather measurements, the most accurate weather forecast available, and using advanced machine learning techniques, we believe we can achieve a significant improvement in the reliability and precision of the calculated ampacity predictions. But a certain degree of error will remain unavoidable. Therefore, operations will need the combination of day-ahead forecasts, robust short-term (1h-4h) predictions and ultimately 100% reliable sag monitoring to achieve the objective.

4. CONCLUSIONS

If we want DLR to become a mainstream tool for TSOs and the planning and operational norm of tomorrow to replace static and seasonal thermal ratings then we need to move beyond the current state of technology and propose truly reliable real-time measurements and predictions for the ampacity of overhead lines. We believe this is achievable and that, once this goal is reached, DLR can play an important part in the significant upgrade of the networks required to evolve towards a fully sustainable energy market.

BIBLIOGRAPHY

[1] Cigre, 2006, Guide for the selection of weather parameters for bare overhead conductor ratings", TB299, WGB2.12.

[2] J.L. Lilien, S. Guerard, B. Godard, J. Destiné. Microsystem array for live high voltage lines monitoring. CIGRE 2006, CIGRE session papers, Group B2 (8 pages).

[3] E. Cloet, J.L. Lilien, P. Ferrières. Experiences of the Belgian and French TSOs using the « Ampacimon » real-time dynamic rating system. CIGRE 2010 Session papers, Group C2, C2-106.

[4] Kiessling et al Overhead Power lines, Springer 2003, page 546, section 14.5

[5] CIGRE Technical brochure N° 324. “Sag-Tension calculation methods for overhead lines”, June 2007

[6]IEEE subcommittee 15.11. “IEEE guide to the installation of overhead transmission line conductors” IEEE Standard 524. 1993

[7] TWENTIES Project : UE SEVENTH FRAMEWORK PROGRAMME THEME ENERGY [ENERGY-2009-7 – SMART ENERGY NETWORKS], Annex I – “Description of Work”, 2010.

WEB

[3] www.ampacimon.com
[7] www.twenties-project.eu