Power Quality Measurement and Wind Turbine Operating Improvement at the CEMIG Morro do Camelinho Wind Farm in Brazil

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1. Introduction

The Brazilian utility Companhia Energética de Minas Gerais (CEMIG) is owner of a wind farm, consisting of 4 stall controlled wind turbines (WTs) with direct coupled asynchronous generators. The wind farm was installed in 1994. Statistics of the last years show a not sufficient performance in energy yield and operation of the wind farm. This undesired operational performance leads to a loss in energy yield and also leads to additional structural loads which can diminish the life time considerably. DEWI's measurements at this wind farm in autumn 1997 gave explanations for the insufficient performance and led to improvements of the operation of the wind farm.

2. Analysis of the Statistical Data

The statistical data of the wind farm of the last two years given by CEMIG showed two different problems:

- The energy output was low.
- The number of starting operations of the WTs was very high.

The achieved energy production of the wind farm of the last two years is only half of the theoretical energy yield, calculated from the mean wind speed of the site and the power curve, given by the manufacturer.

Reasons for low energy yield could be:

- The real power curve is worse than the power curve given by the manufacturer
- The annual mean wind speed is not correct.
- The wind turbines stop for long time periods.

An other problem can be seen in Fig. 1 and 2.

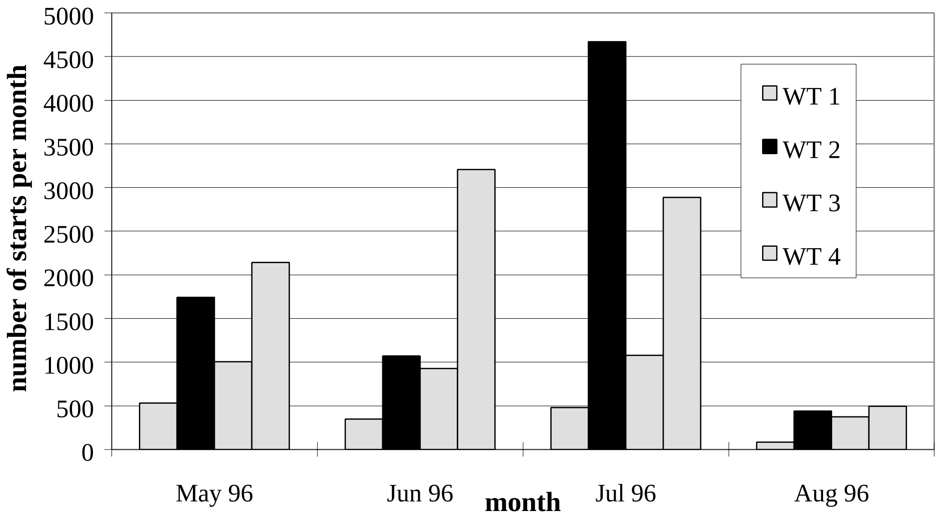

Fig. 1: Number of starting operations per month for each turbine.

The number of starting operations is very high. For example in July 1996 WT 2 showed more than 4600 starting operations. That means an average of more than 10 starting operations per operating hour. On the other hand WT 1 gives only 1 starting operation per operational hour during the same month. The reasons for this could be:

- specific wind conditions at the single WTs
- different operating behaviour (parameter setting) of the WTs
- grid problems

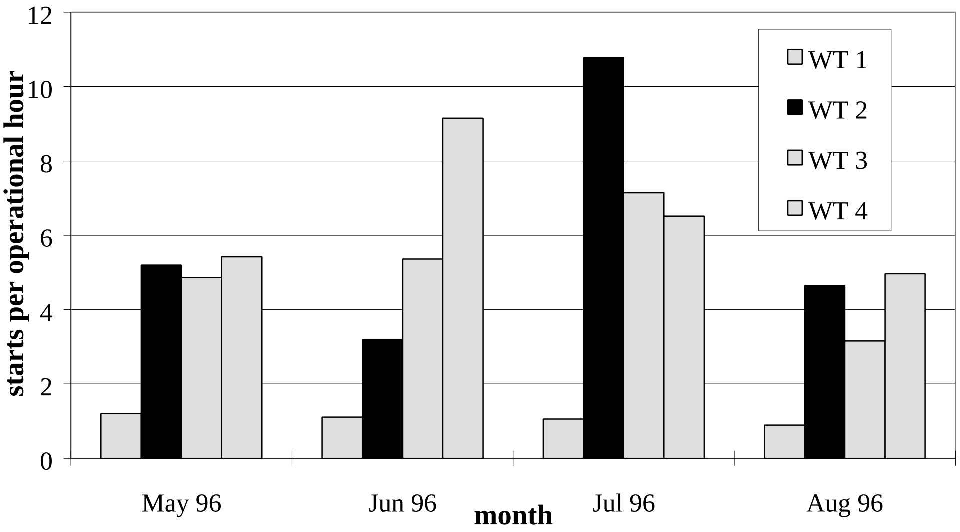

Fig. 2: Number of starting operations per operational hour for each wind turbine.

3. Measurements at the Wind Farm

To find out the reasons for the malfunctions DEWI performed the following measurements at the wind farm and at the single wind turbines during the measurement campaign in autumn 1997:

- Power quality measurements at each WT
- Power quality measurements at the grid in normal grid situation
- Measurements in an isolated island grid, consisting of the wind farm, a hydro power station and consumers

The measurements at the WTs were performed sequentially, that means turbine by turbine. The measurements at the grid were taken in parallel to the measurements at the single WTs. Thus the distortions at the grid could be measured at the same time, when the power quality measurements of the single WTs were performed.

4. Results of the Measurement

The power quality measurements showed, that the WTs behaviour is like other typical stall controlled WTs with direct coupled asynchronous generators. There were no problems of the WT's operation concerning flicker, harmonics, power fluctuations and inrush currents during switchings. But the number of switchings was too high. At low wind speeds, where the active output power of the WTs is nearly zero, the WTs started and stopped very often. Measurements gave 16 switchings in 40 minutes of a single WT. The reason for these frequent switchings was a parameter setting of the control unit, which was not well adapted to the conditions at the wind farm site. The region is very mountainous, with the site of the wind farm on the top of a hill, where the wind is mainly blowing from the direction of a valley between two other hills. Thus the wind speed fluctuation is very high. For example it changes from 3 m/s at the first minute to 8 m/s the next minute and then it decreases again to 3 m/s. This causes frequent wind turbine starts and stops, nearly every minute. Changings of averaging times and of switching levels in the control of the WTs gave a better adaptation to the special wind conditions of the site. Additionally a wrong parameter setting of the WTs led to the effect, that the WTs stopped only for one second. That means, when the wind speed was low and the WTs stopped because of low energy output, they often started again 1 second later. Then the WTs were running for 1 minute and stopped again only for 1 second. This effect could be avoided by a better parameter setting of the WTs. Fig. 3 gives an example for this phenomenon.

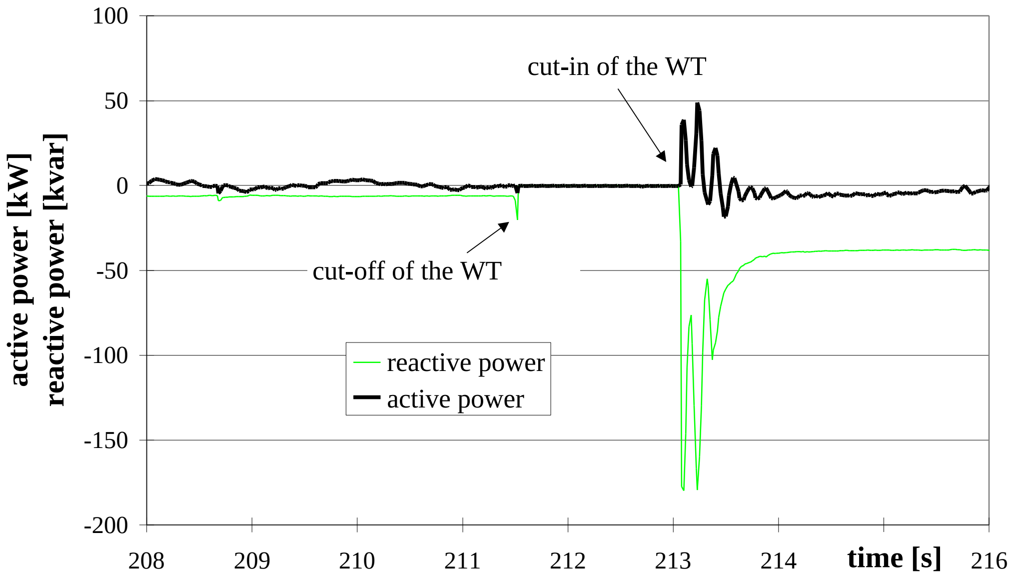

Fig. 3: Cut-off and cut-in of the generator of the WT.

For the investigation of the low energy yield of the wind farm the power curves of all WTs were checked. All power curves are very close to a reference power curve given by the manufacturer. Only in some wind speed ranges they were less than the reference curve. Thus it is obvious that the low energy yield does not have its origin in the individual power curves.
The power quality measurements at the grid showed, that there are only low harmonics and low flicker in the grid. But due to changes in consumer loads the voltage changes in a large range. The minimum voltage during the measurement period was 7 % below the nominal voltage, the maximum voltage reached up to 11 % above nominal voltage. The voltage limits of the WTs control were set in a way, that the voltage changes of the grid do not disturb the operation of the wind turbines. Fig. 4 gives the voltage changes on 23. Sept. 1997 at the medium voltage grid of the wind farm. The frequency of the grid was very stable. During the measuring period, the changes were less than 0.1 Hz. But occasionally a total loss of grid occurred because of short circuits in the overhead lines of the grid.

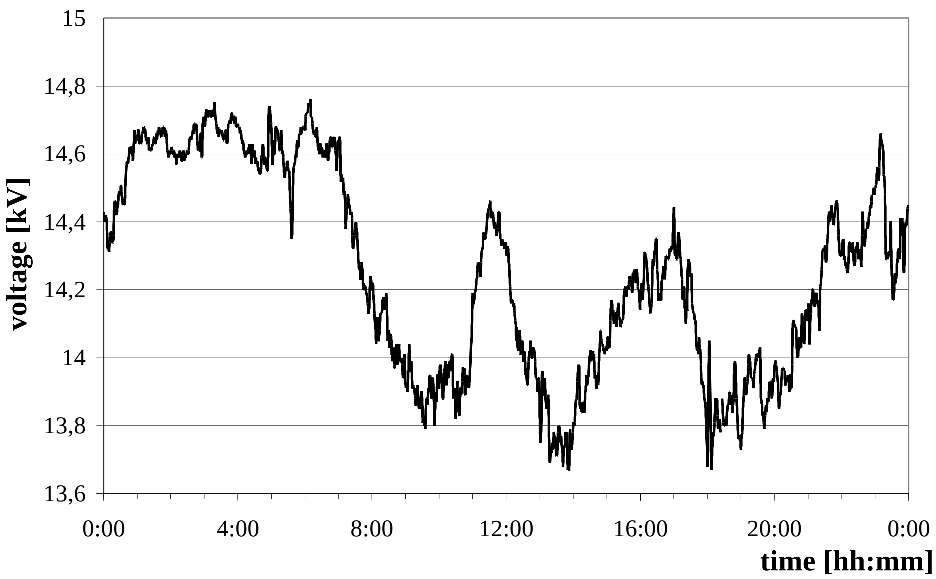

Fig. 4: Voltage changes on 23. Sept.1997 at the medium voltage grid of the wind farm

The data of the statistical measurements showed, that the WTs were stopped several times for longer time periods, which decreased the energy yield of the wind farm considerably. The reason for this may be on one hand real faults. On the other hand there were stand stills like overspeed, after which the WT did not restart automatically. In this case the WTs had to be reset manually, which took long time when nobody was available at the remote site of the wind farm. The power quality measurements showed, that overspeeding occurs when there is a total grid loss. In the first instant when the grid loss occurred, the WTs, the consumer loads and other motors and generators were working in an isolated grid. At this time the asynchronous generators were excited by the capacitors of the power factor correction unit. Because of low loads the frequency of the grid increased driven by the overpower of the WTs and thus also the rotational speed of the WTs increased. If the limit of the overfrequency fault in the parameter settings of the WTs control is higher than the overspeeding limit the WTs'control will detect an overspeeding fault. A change in the parameter settings concerning average times and levels was done, so that the control system in most of the cases now will detect a grid loss and not an overspeeding of the WT. The fault 'overfrequency' or the fault 'grid drop' will be reset automatically, so that there will be less numbers of time periods, where the WTs remain stopped because of the missing manual reset.

At the wind farms site, part of the grid could be disconnected from the main grid. In the remaining isolated grid the wind farm supplied together with the small hydro power station (2 MW) the connected consumers. The measurements showed no problems during the operation of this isolated grid, because the wind speed was low during the measurement period, so that the power output of the WTs did not reach critical high values. At higher wind speeds the balance of generated power of the wind farm and demanded power of the consumers certainly has to be controlled to avoid instabilities of the grid. It should be possible with special parameter settings of the WT's control systems, to switch off turbine by turbine automatically, if the power production of the wind farm exceeds the energy demand of the consumers.

5. Conclusions

The measurements at the CEMIG wind farm showed, that the wind turbines control system were not well adapted to the special wind conditions of this site. Changes in the parameter setting of the WT controls improved the operational behaviour of the turbines and decreased the number of switchings. The power curves of the wind turbines were checked. They all were very close to a reference power curve, indicating that the power performance of the WTs are within acceptable limits. But several stand stills forced by not performed manual resets of detected overspeed faults reduced the energy yield of the wind farm considerably. Improvements in the WT control behaviour decreased the numbers of long stand still periods considerably. Measurements at the grid showed that harmonics and flicker of the grid is low. The frequency is very stable. Only the voltage fluctuated in a range of -7% and +11 %. The WTs also were operated for test purposes in an isolated grid. During the low wind condition of measurement period did not occur any problems. But care has certainly to be taken, if the energy output of the WTs reaches the consumption level of the consumers energy demand.