Experiences from a Back-to-Back Converter fed Village Microgrid

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Abstract—This paper presents the first measurement results of a back-to-back converter fed island microgrid consisting of several holiday cottages in Central Finland. The voltage stability is shown to improve considerably when the microgrid is fed by the converter. The lowest order voltage harmonics caused by nonlinear loads can be compensated. The higher order harmonics of the microgrid and the feeding grid are also at reasonably low level. Further, the capability of the converter is shown to be adequate to feed enough short circuit current to guarantee the correct operation of the fuse based protection of the microgrid.

Index Terms—Converters, fuses, harmonic distortion, microgrids, power quality, virtual direct torque control.

I. INTRODUCTION

The microgrids have now been discussed for about ten years [1] and are now gradually becoming popular also outside of the laboratories. One typical feature of the microgrids is the use of power electronics to interface the various sources of energy and the utility system. Converters can isolate the microgrid from the fluctuations of the utility voltage and thus improve the power quality of the microgrid.

However, protection [2], unbalanced load [3] and harmonics [4] may be problematic when the microgrid is fed from a converter. The usual way to use fuses in short circuit protection means that the converter has to be able to provide enough current to reliably blow the fuse. The unbalanced load causes voltage unbalance and tends to generate oscillations in the converter’s dc link voltage. The harmonics caused by non-linear loads distort the voltage. Further, the switching of the converter’s transistors produces high frequency distortion that has also to be mitigated.

Most of the smart grid publications have dealt with simulations or small scale laboratory setups. Only few large scale experiments have been reported [5], [6].

In Finland, as a part of SGEM (Smart Grids and Energy Markets) project funded by TEKES and participating companies, a converter fed island microgrid has been constructed in order to feed a small village of holiday cottages. The microgrid was commissioned in March 2010 and this paper presents the first measurement results obtained.

II. MICROGRID TEST SITE

The village is located on a peninsula in Central Finland. The distance from the MV/LV transformer is about 1 km of which about 300 m is underwater cable. Due to the long cable and the high load in the village there had been complaints about excessive voltage fluctuations. The need to decrease these voltage fluctuations was one of the reasons why the village was selected as the test site for the microgrid.

Fig. 1 shows the one-line diagram of the test site. The village microgrid is fed through back-to-back 120 kVA IGBT converters with LCL (inductor-capacitor-inductor) filters. The supply side converter takes care of the rectification and the microgrid side converter generates constant frequency and voltage for the microgrid from the common dc link. The neutral for the microgrid is provided by the Dyn transformer. It is possible to bypass the converters for maintenance. Further, the converters can be remotely monitored and controlled via wireless GPRS communication system by the distribution grid operator’s SCADA. For black-outs the communication system has a battery back-up. The whole equipment with transformers is installed in a hermetically enclosed IP65 outdoor cabinet shown in Figs. 2 and 3.
III. TEST RESULTS

A. Power Quality

During commissioning an extensive set of tests and measurements was carried out. In Fig. 4 the microgrid voltage, current and power during load change from no-load to maximum load are shown. Load was typical single-phase household equipment. Furthermore, due to the electric heating the highest loads were resistive. As can be seen the converter control was able to keep the voltage variation at extremely low level during the load changes. In the supplying grid the voltage varied from –4 % to –26 % during the test. Thus the converter could significantly improve the voltage stability in the village.

In Fig. 5 the current and voltage distortion along with the flicker are shown. After the load was connected the voltage THD was less than 3 %. The current THD is naturally the highest at no-load situation.

Fig.4. One minute averages of line-to-neutral rms voltages, currents, active powers and apparent powers of the microgrid during load test.

Fig.5. One minute averages of the THD of the line-to-neutral voltages and currents and corresponding flicker indexes during load test.
The converter had special software that is able to compensate the low order voltage harmonics caused by nonlinear loads. The comparison of the low order voltage harmonics with and without the compensation is shown in Fig. 6.

With the compensation the voltage spectrum is dominated by the spread spectrum harmonics around 1 kHz that are amplified due to the characteristics of the converter filter. However, harmonic levels are in general reasonably low and quite well comply with EN 50160 limits [7], Fig. 7.

The higher frequency voltage spectrum of the microgrid from 2.5 kHz to 9 kHz is shown in Fig 8. The spread spectrum harmonics are typical to the virtual DTC (Direct Torque Control) principle used in the converters [8], [9]. By spreading the harmonics into many low amplitude components instead of few harmonics with very high amplitude the risk of severe grid resonance is decreased. The advantage can be seen from the Fig. 9 where the harmonic magnitudes are low in spite of the parallel resonance between the supply network’s cable and MV/LV transformer that amplifies the voltage harmonics around 4.5 kHz. It is also important to note that DTC is able to damp the LCL filter’s resonance. Thus efficiency degrading damping resistors are not required in the LCL filter.

The protection system in the cottages is standard fuse based one. The correct operation of fuses requires high enough short circuit current from the island grid source. The performance of the converter in three-phase, two-phase and single phase faults are shown in Figs. 10-12. The fuses used in the tests were 32 A Gg type. When the short collapses the voltage, the converter ramps the current up to about the rated current of the converter. The fuse blows and clears the fault in less than one second. After that the voltage is smoothly ramped up to the rated value. If the fault is not cleared in 15 seconds the converter is shut down.

IV. CONCLUSIONS

A converter for feeding of a microgrid has been successfully commissioned. The power quality of the microgrid could be significantly improved by the converter.
The proper operation of the fuse protection system has been verified by short circuit tests.

During the two months operation recorded now, several autoreclosures have been encountered in the supplying grid. However, these have not caused loss of voltage in the microgrid. Thus it seems that the dc link capacitance is sufficient for the microgrid to ride through short interruptions.

The inhabitants have been very satisfied with the power quality. The only complaint from the inhabitants in the village was the acoustic noise caused by the cooling fans of the converter cabinet. At the moment measures to decrease the hum are devised.

Regarding the future, the converter system allows the addition of distributed generation to the microgrid. Such devices could be connected either to the microgrid or to the dc link of the converters. The back-to-back construction allows the extra energy to be fed back to the supplying grid.

Further, it is possible to add energy storage to the dc link of the converters. With the energy storage the present 0.5 s voltage dip ride through capability could be extended significantly.

Moreover, the concept can be expanded to a low voltage dc distribution network [10]. For example, the supply side converter could be moved to the MV/LV transformer and the ac cable be replaced by a dc cable.

V. References

VI. BIOGRAPHIES

Jouko Niiranen (M’88–SM’03) was born in 1953 in Finland. He received the M.Sc. and Dr. Tech. degrees in electrical engineering degree from Helsinki University of Technology, Helsinki, Finland, in 1980 and 1990, respectively. Currently, he is Corporate Executive Engineer with ABB Oy, Drives, Helsinki. He started with Stromberg (later ABB) Traction Drives in 1981. From 1989 to 1993, he was as a Researcher with the Power Electronics and Electric Drives Laboratory, Helsinki University of Technology. Since 1993, he has worked with ABB in various research positions. He has also been an Adjunct Professor at Helsinki University of Technology since 1994. His main areas of research interest are modeling and simulation of renewable generation systems, control of high-performance drives, and power electronic converters.

Mikko Routimo (S’06–M’09) was born in Harjavalta, Finland, in 1977. He received M.Sc., L.Sc., and D.Sc. degrees in electrical engineering from Tampere University of Technology, Tampere, Finland, in 2002, 2005, and 2009, respectively. He was a researcher at the Institute of Power Electronics, Tampere University of Technology from 2002 to 2008. In 2008 he joined ABB Oy Drives in Helsinki, Finland. His areas of interests include PWM converters, their control, and power quality.

Reijo Komsi was born in 1953 in Finland. He received his M.Sc degree in 1995 (Power Electronics and Electric Drives) in Helsinki University of Technology, Finland. Komsi started in Stromberg (later ABB) in 1982. During 1982-1998 he worked as electronics, power electronics and SW designer in product development of System Drives. Since 1998 as a product manager he has been responsible for the active rectifier development in industrial and wind turbine applications. He is specialized in active rectifier control and power quality. He has developed special distortion calculation tools for different kinds of rectifiers and for different line filter topologies.

Mr. Komsi and his team are presently responsible for the development of control SW for active rectifiers and simulators for industrial drives and distributed generation. Moreover, he has three patents approved on the technology of electric drives.

Tommi Lähdeaho was born in Vilppula, Finland, in 1982. He received M.Sc. degree in electrical engineering from Tampere University of Technology, Tampere, Finland in 2007. In 2007 he started in Vattenfall Networks Finland. His responsible area is electrical planning and power quality.

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