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POWER QUALITY IMPROVEMENT FOR A WIND FARM CONNECTED GRID INCORPORATING UPFC CONTROLLER

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Abstract— **The wind generated power is always fluctuating due to its time varying nature and causing stability issues when it is incorporated with the power system network. In this paper, control circuit of Unified Power Flow Controller (UPFC) is proposed and developed to improve the power quality issues in wind energy conversion systems. Three phase fault involving ground is simulated using MATLAB and tested for an IEEE 5 bus system with wind powered generator. When fault is simulated at the terminals of WECS, PCC voltage reduced to a very low value. Results shows that voltage at PCC, real power and reactive power are improved by the incorporation of UPFC. Validation of the proposed controller design of UPFC is also tested for a real time wind powered generator connected grid.**

Index Terms—**FACTS, UPFC, power quality , real power, reactive power .**

I. INTRODUCTION

In recent years, wind energy has become one of the important and promising sources of renewable energy. But incorporation of large amount of wind energy in power network will result in fluctuating real power injection and varying reactive power absorption which leads to voltage flactuations and affect the stability and power quality of the system. Flexible AC Transmission System (FACTS) devices can give solution for the variations created in power system by such types of renewable resources and helps to improve its stability, power transfer capability and control of power flow. FACTS controllers provide the necessary dynamic reactive power support and the voltage regulation at the Point of Common Coupling . Here the Unified Power Flow Controller is chosen for the power quality improvement because the UPFC allows simultaneous control of all three parameters of power system that is the line impedance, voltage magnitude and power angle. It is primarily used for independent control of real and reactive power in transmission lines for flexible, fast, reliable and economic operation.

In the WECS most commonly used generators are wound rotor induction generators. Induction generators draw reactive power from the main power grid and hence might result in voltage drops at the PCC. Moreover, the input power to these induction machines is variable in nature and hence the output voltages are unacceptably fluctuating.

More research has been done on FACTS devices and discussed on controllers like Static Var Compensator and STATic synchronous COMpensator to improve voltage ride-through of induction generators [1], The article [2] gives an approach based on Differential Evolution for optimal placement & parameter setting of UPFC for improving power system security. Research on control design to improve the dynamic performance of a wind turbine for induction generator unit [3], and also how the FACTS devices could be used for the power transfer capability improvement using fuzzy controller is explained in [4]. Many authors have discussed on power quality improvement in WECS, voltage regulation, reactive power power support and transient stability improvement [5-8].

In this paper, UPFC control scheme is used for the grid connected wind energy generation system for power quality improvement and it is simulated using MATLAB/SIMULINK. When a three phase to ground fault occurs, the voltage at the WECS terminals drops, Thus the generated active power falls. After fault clearance, the reactive power consumption increases resulting in reduced voltages at the PCC. Here test case1 considered is a IEEE 5 BUS system and case 2 is real time grid system. Here results shows that, UPFC connected at the terminals of WECS results in the voltage improvement at PCC and real and reactive power improvements that in turn gives the power quality improvement.

II. POWER QUALITY ISSUES

Perfect power quality means the voltage is continous and sinusoidal having a constant amplitude and frequency. It is described in terms of voltage, frequency, and interruptions. Grid connected wind turbines do affect the power quality. Power quality depends upon the interaction between the grid and the wind turbines. There are two types of loads, linear and nonlinear. Motors, heaters and incandescent lamps are examples of linear load that consumes a current proportional to the voltage. The nonlinear load uses high-speed electronic power switching devices to convert the AC supply voltage to a constant DC voltage used by the internal circuits. During converting, harmonic currents on the power grid are generated. Production of harmonic currents at PCC cause several adverse effects such as line voltage distortion at PCC, equipment overheating, electronic lighting ballasts, ferromagnetic devices, failure of sensitive electronic equipment, flickering of fluorescent lights, adjustable speed drives, dc motor drives and arcing equipment are examples of nonlinear loads.

Voltage Unbalance, According to the electricity board, the variation in the steady state voltage is in the range from + 5% to –5% at the wind turbine terminals in the wind farms [9]. Too low voltages can cause the relay protection to trip the wind turbines. Voltage flicker is dynamic variations in the network. Flicker produced during continuous operation and is caused by power fluctuations, which mainly emanate from variations in the wind speed, the tower shadow effect and mechanical properties of the wind turbine. Flicker due to switching operations arises from the start and shut down of the wind turbines [10][11]. Frequency Range, According to electricity boards and manufacturers, the grid frequency in India can vary from 47 to 51.5 Hz. Most of the time, the frequency is below the rated 50 Hz. For wind turbines with induction generators directly connected to the micro grid, frequency variation will be very considerable. Frequency variation is directly affected by the power production of wind mill. Harmonics, Grid connected wind turbines through power converters however emit harmonic currents that create the voltage distortion. Power electronic loads, rectifiers, inverters are the sources that produce the harmonics. Due to this harmonics the wind turbine generators affected leading to generator over heating, low power factor, increased generator vibration. Transients, are of very short duration that will vary greatly in magnitude. When transient occur, thousands of voltage can be generated into the electrical system, causing problems for equipment down the line [10][11].

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III FACTS CONTROLLERS FOR POWER QUALITY IMPROVEMENT

The FACTS devices are based on power electronic controllers used in the transmission line for the better utilization of existing transmission system with increased transmission capacity and system reliability. FACTS devices increases dynamic and transient grid stability. These controllers are fast responding when controllers are properly tuned. FACTS devices are mostly used to regulate the voltage and power flow through the lines. UPFC is a flexible controller and it is used in this research work for the power quality improvement in the WECS connected to grid.

IV PROPOSED SYSTEM CONFIGURATION

All the three parameters of line power flow (line impedance, voltage and phase angle) can be simultaneously controlled by the Unified Power Flow Controller device. UPFC is a device that combines together the features of two devices STAtic synchronous COMpensator (STATCOM) and the Static Synchronous Series Compensator (SSSC)[12]. These two devices are two Voltage Source Converters connected respectively in shunt with the transmission line through a shunt transformer and in series with the transmission line through a series transformer, connected to each other by a common dc link including a storage capacitor. Filters are connected across capacitor to prevent the flow of harmonic currents generated due to switching. At the output of the converters ,the transformers are used to give the isolation and modify voltage/current levels and also to prevent DC capacitor getting shorted by the operation of various switches. Insulated Gate Bipolar Transistors (IGBTs) are the power electronic devices used with anti-parallel diodes for shunt and series converters .The shunt inverter is used for voltage regulation at the point of connection, injecting an opportune reactive power flow into the line and to balance the real power flow exchanged between the series inverter and the transmission line. The series inverter can be used to control the real and reactive line power flow inserting an opportune voltage with controllable magnitude and phase in series with the transmission line. Thereby, the UPFC can fulfill functions of reactive shunt compensation, active and reactive series compensation and phase shifting.

V. CONTROL OF PROPOSED SYSTEM

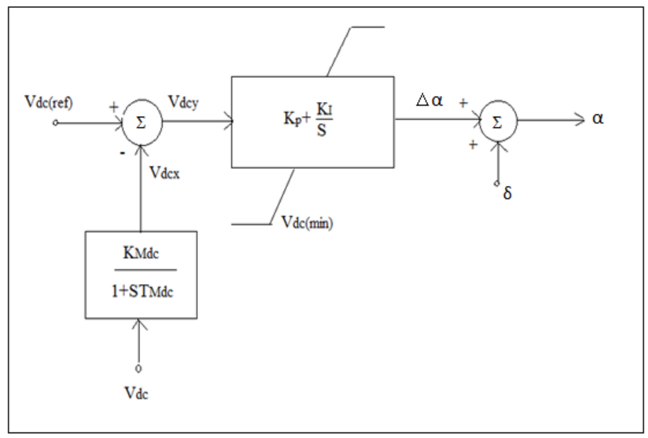

Fig.1 shunt controller of UPFC

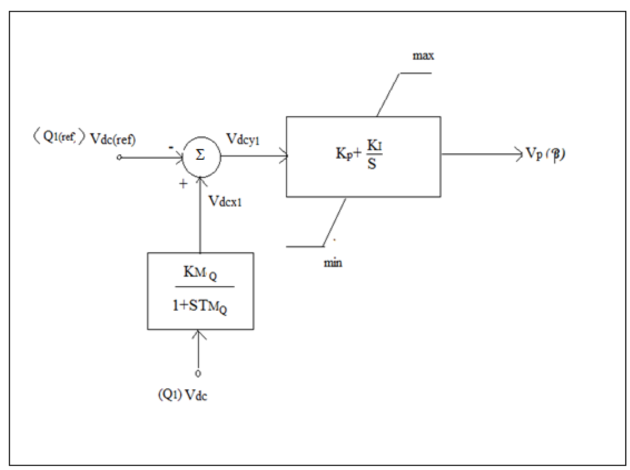

Fig.2 Series controller of UPFC

In order to control the bus voltage, sending-end voltage(Vs) is measured instantly and subtracted from its reference value ($Vs_{\_ref}$) ,which gives the error. This error signal has been given as inputs to a PI block [13]. The output of PI controller gives the magnitude of injected shunt voltage similarly, DC link capacitor voltage (V_{dc})is also measured and subtracted from its reference value (V_{dc_ref}) to get error. This error signal has been given as input to a PI block to obtain the angle. Pulse Width Modulation (PWM) technique is used to generate the pulses for IGBT. Reference signal is compared with carrier (triangle) signal and the outputs of the comparators are given to the converter switches as firing signals .

VI. DESIGN OF PROPOSED SYSTEM

In case 1 the UPFC performance has been tested in an IEEE 5 bus system for power quality improvement.

In this test system shown in Fig.3, the buses 1 and 2 are generator buses . Here bus 1 considered is an IG based wind farm and buses 3, 4, 5 are load buses (PQ buses). The base case has been taken as 11KV and 18 MW. A three phase to

TEST CASE1:IEEE 5 BUS SYSTEM

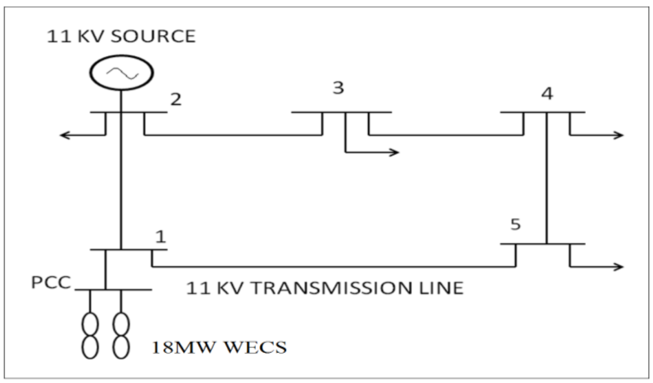

Fig.3 Single line diagram of IEEE 5 bus system

ground fault is applied near WECS from 1 sec to 2 sec. After connecting UPFC across PCC of WECS and bus1, improvement has been observed in the PCC voltage, real power and reactive power. The simulation results of PCC voltage, real power, reactive power with and without UPFC are shown in Fig.7, Fig8, and Fig.9 respectively.

CASE 2 : GRID CONNECTED REAL TIME WECS

The load values considered here are the real time load demands of wind farm connected to 11 KV bus. UPFC performance has been tested here for power quality improvement. In this system a three phase to ground fault is applied near WECS from 1 sec to 2 sec and the performance of UPFC is tested such that results shows that the real power, reactive power and voltage at PCC has improved. Fig.4 shows the single line diagram of WECS connected to real time load.

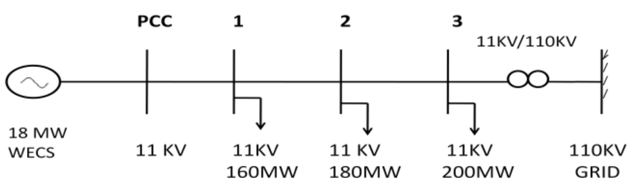

Fig.4 Grid connected WECS

VII. SIMULATION CIRCUITS WITH RESULTS

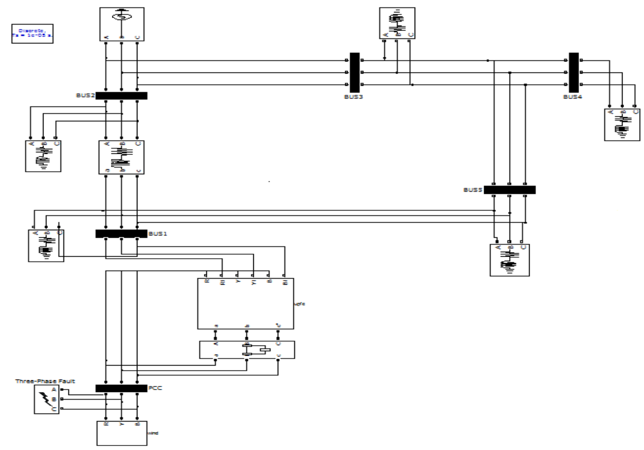

Fig.5 Simulation diagram of IEEE 5 bus system

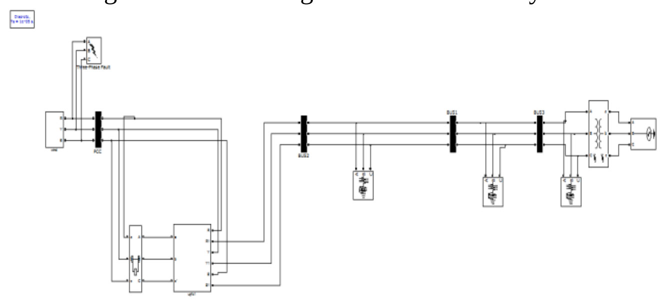

Fig.6 Simulation diagram of grid connected WECS

CASE1: IEEE 5 BUS SIMULATION RESULTS

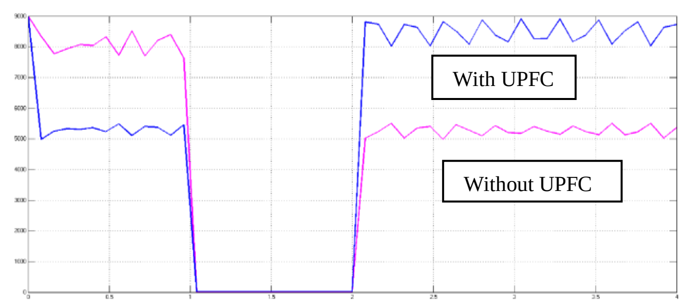

Fig.7 PCC voltage with and without UPFC

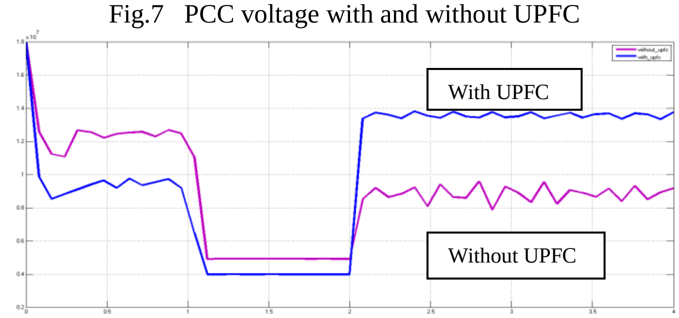

Fig.8 Real power with and without UPFC

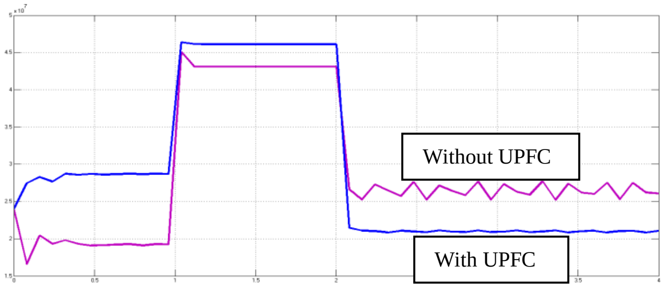

Fig.9 Reactive power with and without UPFC

CASE 2: SIMULATION RESULTS OF GRID CONNECTED WECS

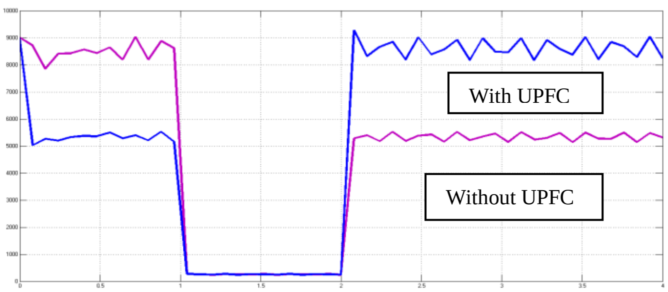

Fig.10 PCC voltage with and without UPFC

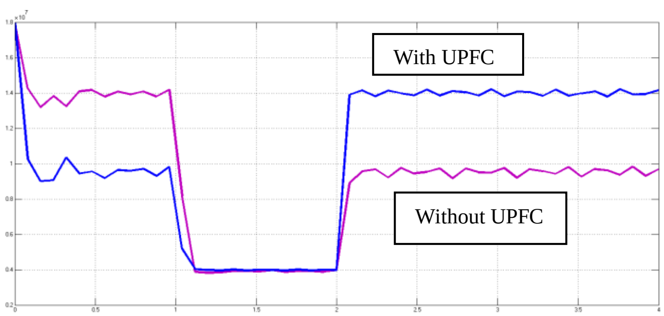

Fig.11 Real power with and without UPFC

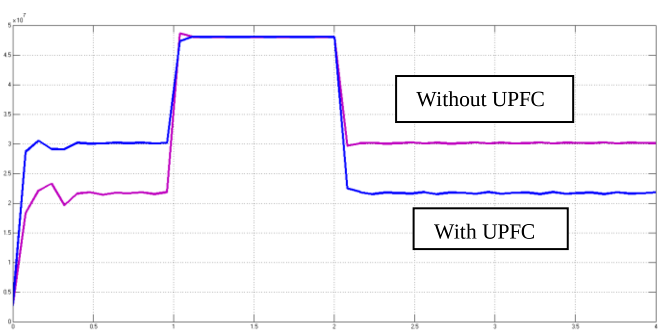

Fig.12 Reactive power with and without UPFC

VIII. DISCUSSION ON RESULTS

TEST CASE 1:It is found that during the presence of fault the PCC voltage without incorporating UPFC reduced to a very low value and after clearance it maintained at the value of 5350 volts. As soon as UPFC has been connected, the PCC voltage increases to 8700 volts. It can also be observed that when fault occurs the real power settles at 9MW without UPFC .With incorporation of UPFC it has increased to 13.8MW. It is found that when fault occurs the reactive power settles at 27MVAR without UPFC , it can be observed that after connecting UPFC it reduced to 21MVAR.

TEST CASE 2: It is found that during fault the PCC voltage without UPFC reduced to very low value and after clearance it maintained at value of 5300 volts. As soon as UPFC has been connected, the PCC voltage increases to 8700 volts .It can also be observed that during fault real power settles at 9.7MW without UPFC and after incorporation of UPFC it has increased to 14MW. It is found that when fault occurs the reactive power settles at 30 MVAR without UPFC , it can be observed that after incorporating UPFC it reduced to 21MVAR.

IX. FFT ANALYSIS

FFT ANALYSIS FOR IEEE 5 BUS SYSTEM

The power quality analysis is done in IEEE5 bus system and also induction generator based grid connected wind power generating system using the FFT tool of the powergui.

The Total Harmonic Distortion in FFT analysis of PCC voltage without UPFC controller for IEEE 5 bus system is 8.53% and is shown in figure 13, and that of PCC voltage with UPFC controller is 5.03% and is shown in figure.14.

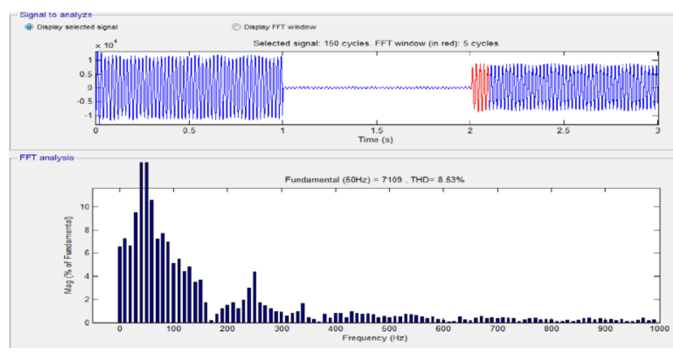

Fig.13 FFT analysis of PCC voltage without UPFC

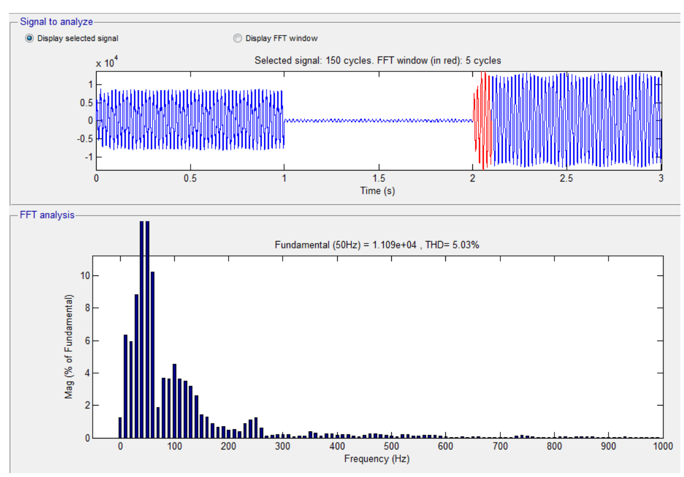

Fig.14 FFT analysis of PCC voltage with UPFC

FFT ANALYSIS FOR GRID CONNECTED WIND FARM

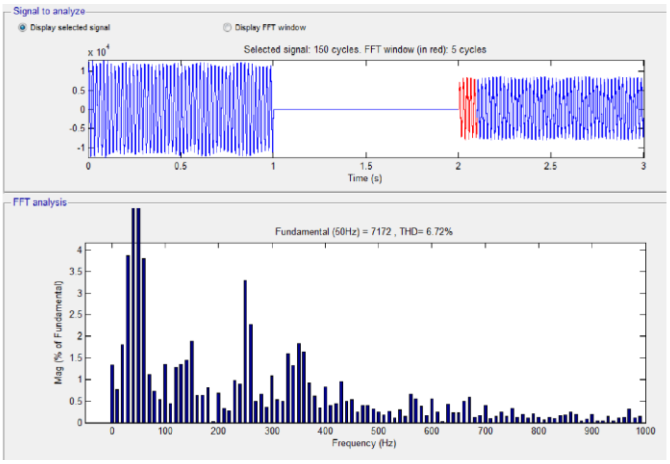

Fig.15 FFT analysis of PCC voltage without UPFC

The Total Harmonic Distortion in FFT analysis at PCC voltage for grid connected wind farm without UPFC controller is 6.72% shown in figure.15 and with UPFC controller it is reduced to 2.01% shown in figure.16. From the figures it can be observed that the UPFC controller helps to mitigates the harmonic distortion in the transmission line.

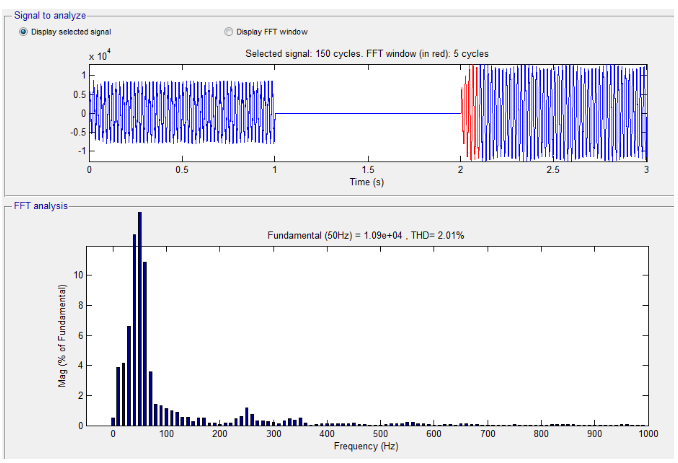

Fig.16 FFT analysis of PCC voltage with UPFC

IX. CONCLUSION

The performance of the proposed method has been simulated for an IEEE 5 bus system and a real time wind farm connected grid UPFC is connected at PCC to compensate the voltage sag created by fault. It is observed that real power flow obtained has increase and reactive power absorption got in result has been decreased after fault clearance by incorporating UPFC at PCC. Total Harmonic Distortions has been reduced using proposed UPFC controller. Therefore, it is concluded that the proposed UPFC control results in power quality improvement of grid with wind farm.

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BIBILOGRAPHY

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