FUNCTION DESCRIPTION

Functional Design Specification Central Wind Farm Controller

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Abbreviations

A	Ampere
CU	Copper
CWFC	Central Wind Farm Controller
GIS	Gas Insulated Switchgear
HMI	Human Machine Interface
IED	Intelligent Electronic Device
kV	Kilo Volt
kA	Kilo Ampère
LWFC	Local Wind Farm Controller
MV	Medium Voltage
N/A	Not Applicable
P&C	Protection and Control
PCC	Point of Common Coupling
SA	Substation Automation
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
V	Volt
WEC	Wind Energy Converter
WTG	Wind Turbine Generator

Related documents

Document number	Title
SOC_11-175	D4-Wind_Farm_Connection_Requirements_5_9
180507	F1-WPZ Functional Requirements Wind Farm Controller 1.0
081116	D5-Compliance Wind Farms V 4.2 Clean
181116	D6-Data Exchange Wind Farms V 5.3
180513	F2-WPZ Functional Scheme power management 1.0
E0014032-E03-FP1-000002	I/O list CWFC

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Ugur Cicek	Project Engineer	10-03-2020	
Karsten Schoenmaker	Author	10-03-2020	

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Vogelweg HV station B.V.				1
ABB Power Grids The Netherlands B.V.	PGGA	Eric Niekerk	10-03-2020	1
		Karsten Schoenmaker	10-03-2020	1
		Document control	10-03-2020	1

Vogelweg HV station B.V.

Visit Address Landauer 2 3897 AB Zeewolde

Postal Address

ABB Power Grids The Netherlands B.V.

Introduction

This Functional Design Specification describes the soft- and hardware configuration of the Central Wind Farm Controller (CWFC) intended for Wind Farm Zeewolde. The purpose of the CWFC is to ensure grid compliance by coordinating the efforts of six Local Wind Farm Controllers (LWFC) by acting as a master controller. The main function will be controlling the active & reactive power at the Point of Common Coupling (PCC). The CWFC will also function as a gateway in providing information from the LWFC's to the Substation SCADA system.

1 General

1.1 Scope of document

The main function of this design specification is to provide a clear view, how we envision the central wind farm controller as part of the wind farm.

This document will serve as a continued working- and discussion basis for the actual realization of the CWFC.

1.2 Scope of design

The central wind farm controller will be in charge of maintaining grid compliance. To achieve grid compliance the Windfarm must comply with the TSO regulations as specified in SOC 11-175. The PCC will be the reference point for determining Grid Compliance.

To achieve Grid Compliance the CWFC will be able to regulate the active and reactive power provided by the WTG's. The CWFC will also be able to coordinate the efforts of multiple LWFC's in order to manage the active and reactive power. Design will be according to requirement 448 [1].

1.3 Conventions of the sign of active and reactive power

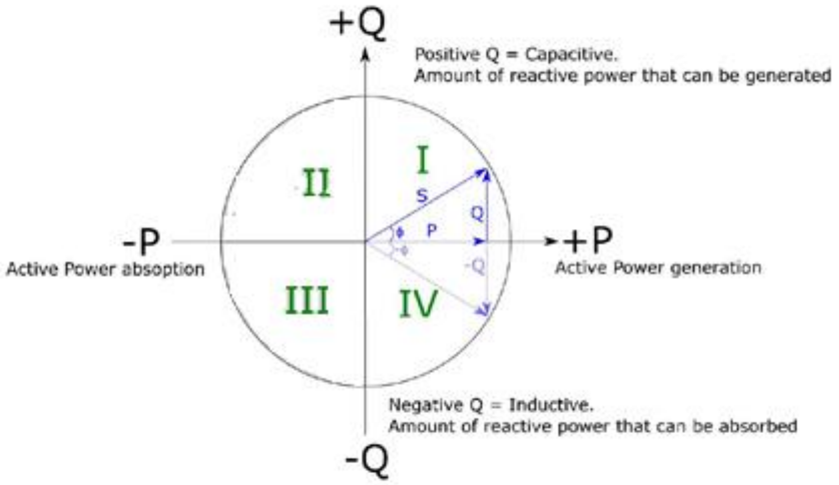

Figure 1 Power Sign Convention

2 System Architecture

2.1 Wind Farm General overview

The CWFC will communicate with all involved parties over the IEC60870-5-104, as shown in the overview below.

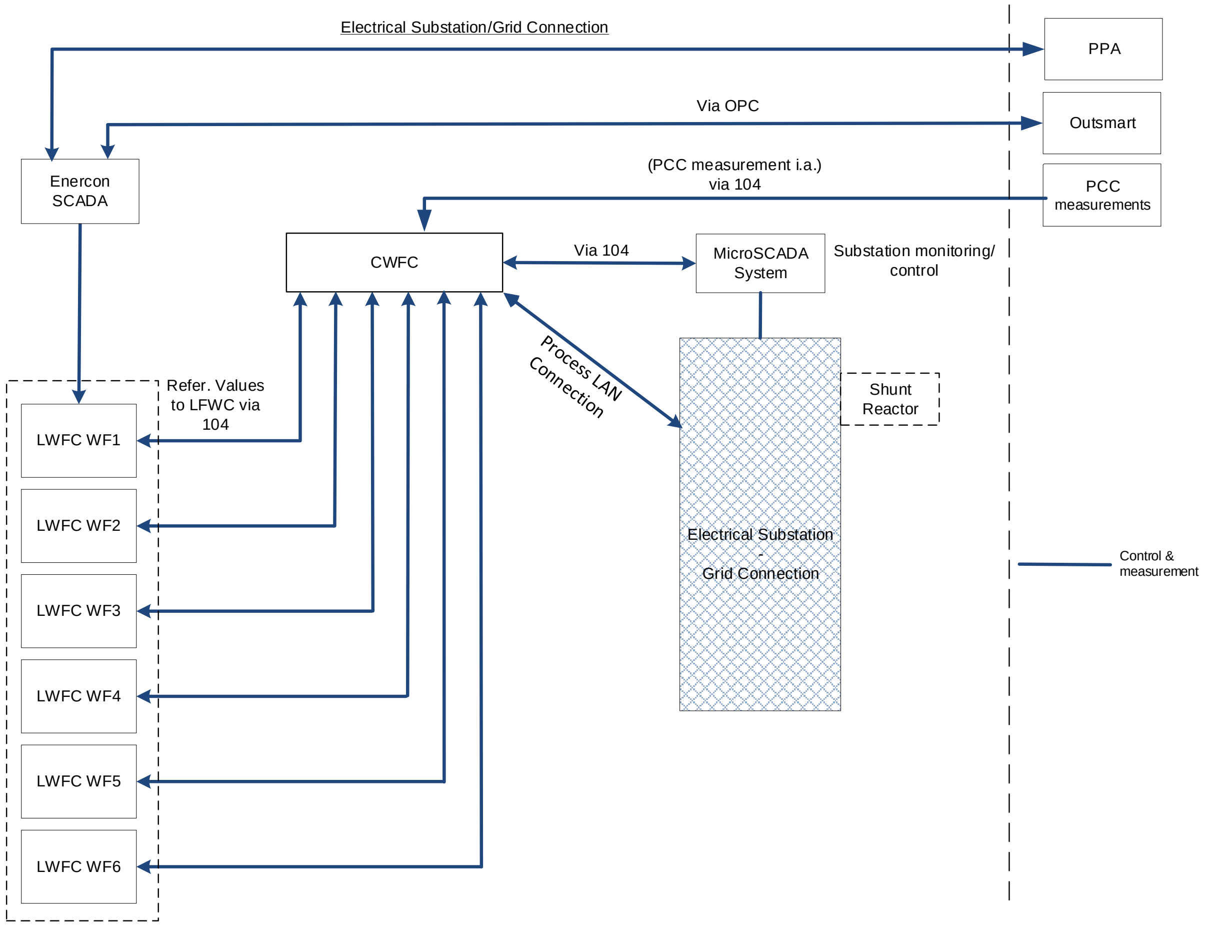

Figure 2 System Architecture Overview

The PPA will access the WTG SCADA directly with regards to monitoring data and performing curtailment. As discussed on 8-1-2020. Proposed by Outsmart.

Tennet B.V. will no longer connect directly to the CWFC. Outsmart will communicate with Tennet directly via phone, when this is necessary. The CWFC will be configured in a way that minimal adjustments are needed in case Tennet will be connected to the CWFC directly according to [3]. As discussed on 21-1-2020.

2.2 Central Wind Farm Controller Architecture.

This paragraph shows the general architecture of the Central Wind Farm Controller.
The systems connected to the CWFC are the LWFC and the System Operator.
The TSO will not be connected but preparations have to be made for the TSO to be able to pass on setpoint requests, send/receive data routed through the gateway function.
The System Operator will have the ability to pass on setpoint requests, select new Control modes and send/receive data routed through the gateway function.

The Local Wind Farm Controllers will receive setpoints from the CWFC and provide information regarding the available P & Q.

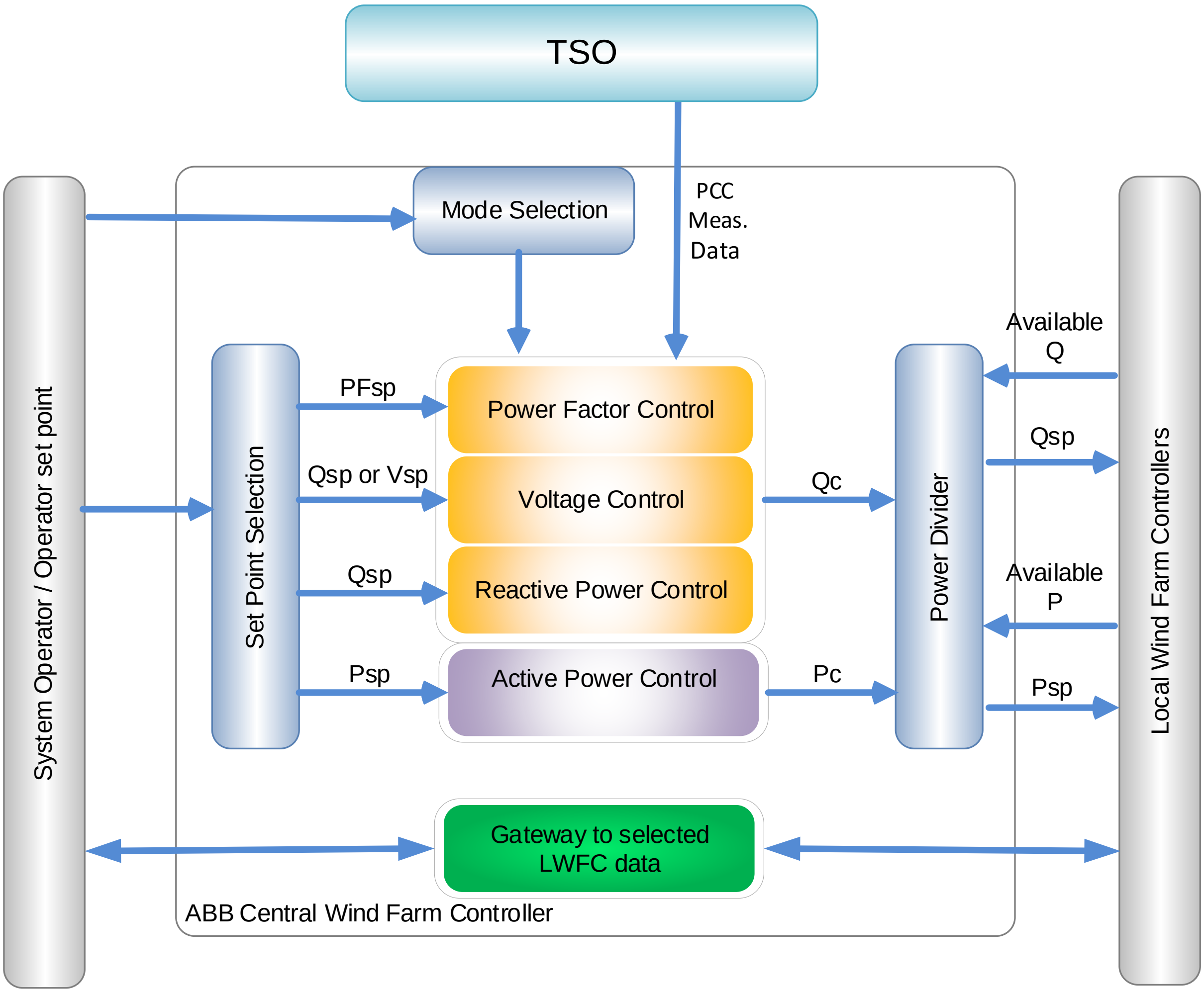

Figure 3 CWFC Architecture Layout

- Setpoint selection
- Reactive Power Control Mode Selection
- Power Divider
- Data concentrator / Gateway LWFC->CWFC

2.3 Active Power Control

Active Power Control will regulate the active power from the WEC's to the Grid. Generally the maximum available power will be used as setpoint. It will also be possible to enter a setpoint. Also called "Absolute Production Constraint". As requested in [2] subsubparagraph 4.2.2.2

The P divider will dynamically calculate the setpoints for the LWFC.

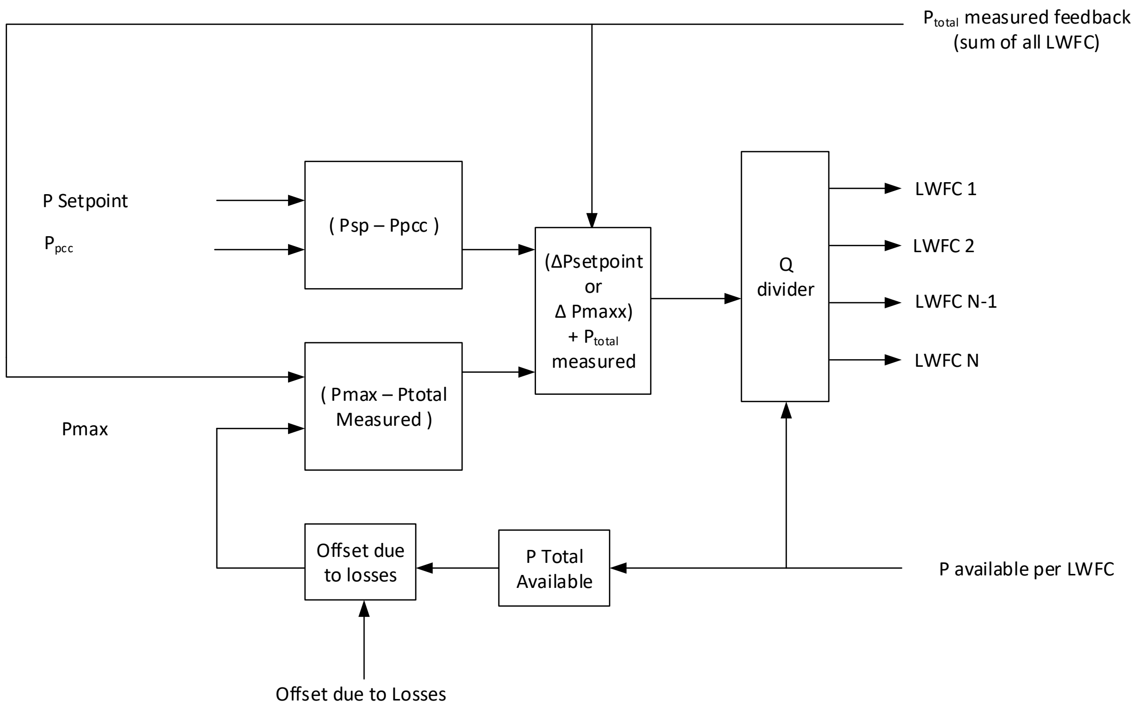

Figure 4 Diagram active Power Control

If P at the PCC is equal to the "P setpoint" or "P max" then the P total measured (LWFC's) should be equal to "P setpoint" or "P max" respectively. This applies when the system is in a settled state.

The local wind farm controller will divide the supplied setpoint into setpoints to the WEC units. The WEC unit setpoint must be calculated in a way that it will compensate for the "Line Losses" and "Phase Rotation" caused by the cables in order to be able to match the values measured by the LWFC to the received setpoint.

Setpoint Ramp & Gradient constraint will be handled via the LWFC.

2.4 Reactive Power Control Modes

The CWFC will have three control modes for regulating the reactive power at the Grid Connection Point. As requested in [2] subsubparagraph 4.2.2.1

- Voltage Control Mode (sub mode 1 & 2)
- Power Factor Control
- Reactive Power Control

The next paragraphs will give an overview how the reactive power control modes will be implemented.

2.4.1 Voltage Control Mode sub mode 1

Voltage control (U-control), characterized by Voltage Droop, Set Point Voltage, with additional functionality to periodically check and if necessary adjust locally the Set Point Voltage to bring the Reactive Power Exchange at the PCC to the Reference Steady State Reactive Power Exchange.

During normal operation of Voltage Control Mode sub mode 1 the system will measure the voltage at the PCC and compare this with the U setpoint. If the value deviates, reactive power exchange will be increased or decreased according to the voltage droop settings.

While the Voltage control mode is active there will be periodic checks if the Voltage and Reactive Power at PCC exceed dynamic threshold or disturbance threshold.

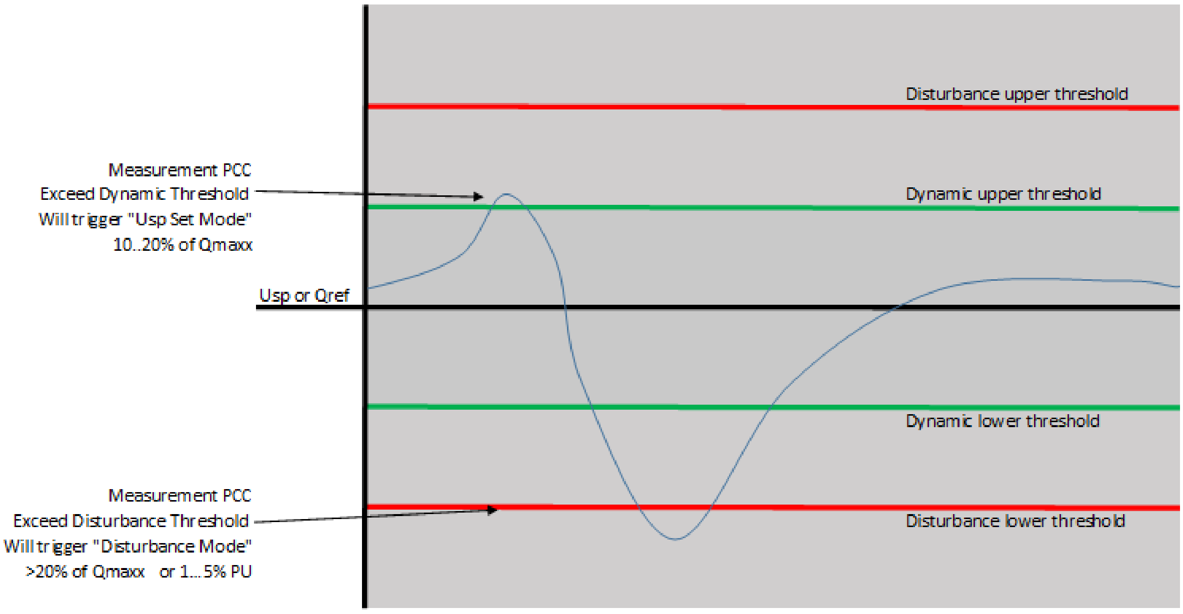

Figure 5 Chart stating ΔQ or ΔU over time

Exceeding the “Dynamic Upper/lower Threshold will trigger the “Usetpoint set” mode and it will set Usetpoint to match the Upcc at the point where Qpcc = Qref.

The CWFC will have the ability to determine locally the Set Point Voltage based on the Agreed Steady State Reactive Power Exchange at the PCC indicated by the Reference Steady State Reactive Power Exchange. The CWFC must have the ability to process the Reference Steady State Reactive Power Exchange indicated by the Network Operator.

When the Disturbance threshold is surpassed the system will go into disturbance mode. During this mode the Reactive power will be held for 15minutes before returning to normal operations.

During a voltage drop/rise larger than the droop percentage the maximum Q available will be injected/absorbed.

If Q at the PCC is equal to the “Q ref” then the Qtotal measured by the LWFC should be equal to “Qoffset”. This applies when the system is in a settled state.

The local wind farm controller will divide the supplied setpoint into setpoints to the WEC units. The WEC unit setpoint must be calculated in a way that it will compensate for the “Line Losses” and “Phase Rotation” caused by the cables in order to be able to match the values measured by the LWFC to the received setpoint.

2.4.1.1 Block Diagram Voltage Droop Control Mode 1

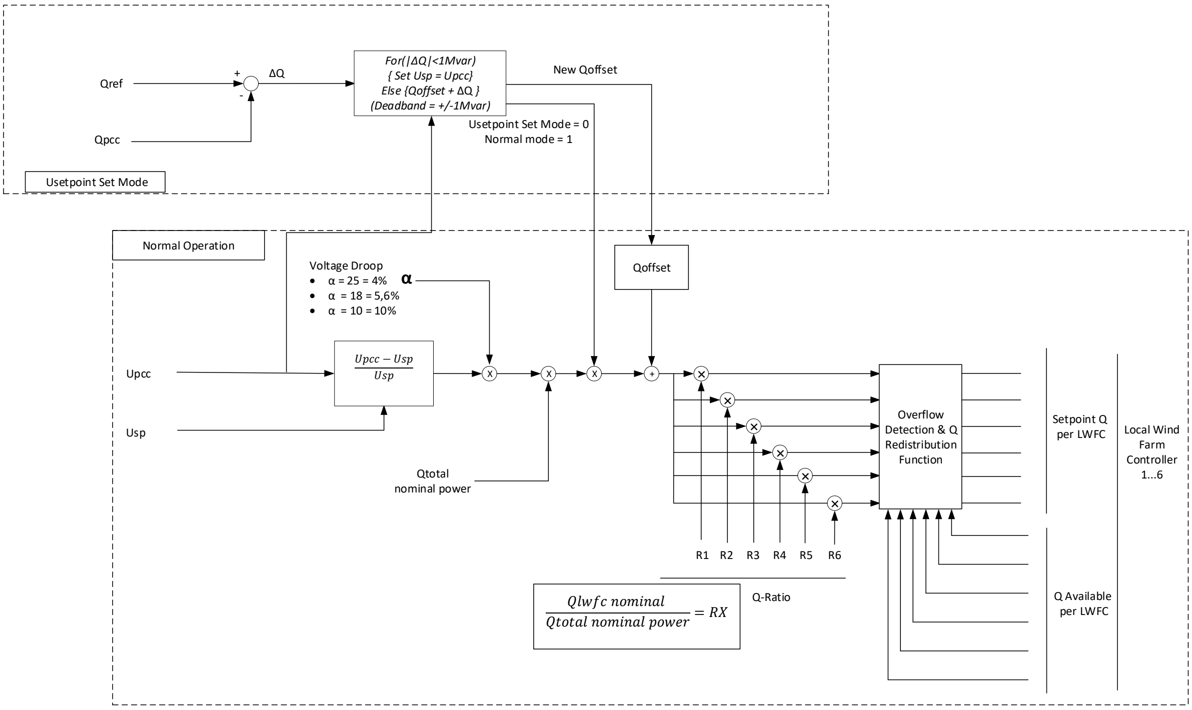

Figure 6 Block diagram voltage power control mode1

$$Qsetpoint\ LWFCx = \left(\alpha * \left(\frac{Usetpoint - Upcc}{Usetpoint} \right) * Qmax + Qoffset \right) RX$$

The alpha coefficient represents the Droop percentage.

- 25 = 4%
- 18 = 5,6%
- 10 = 10%

The Q divider will use static ratio’s. RX is the factor that divides the calculated Q over the LWFC output.

The Overflow Detection and Redistribution Function will detect the event where a Qsetpoint will become bigger than the Q available per LWFC. The amount of Q un-accounted for will be redistributed over the other LWFC’s that still have an unac-counted amount of Q available.

2.4.2 Voltage Control mode submode 2

Voltage control (U-control), characterized by Voltage Droop, Set Point Voltage

The CWFC must have the ability to process the Set Point Voltage indicated by the Network Operator. So it will periodically check if there is a new setpoint given.

The Voltage Control mode Sub mode 1 will measure the voltage at the PCC and compare this with the Voltage setpoint. If the value deviates, reactive power exchange will be increased or decreased according to the voltage droop settings.

There is no automatic “Setpoint Set Mode” or “Disturbance” mode.

During a voltage drop/rise larger than the droop percentage the maximum Q available will be injected/absorbed.

2.4.2.1 Block Diagram Voltage Droop Control Mode 2

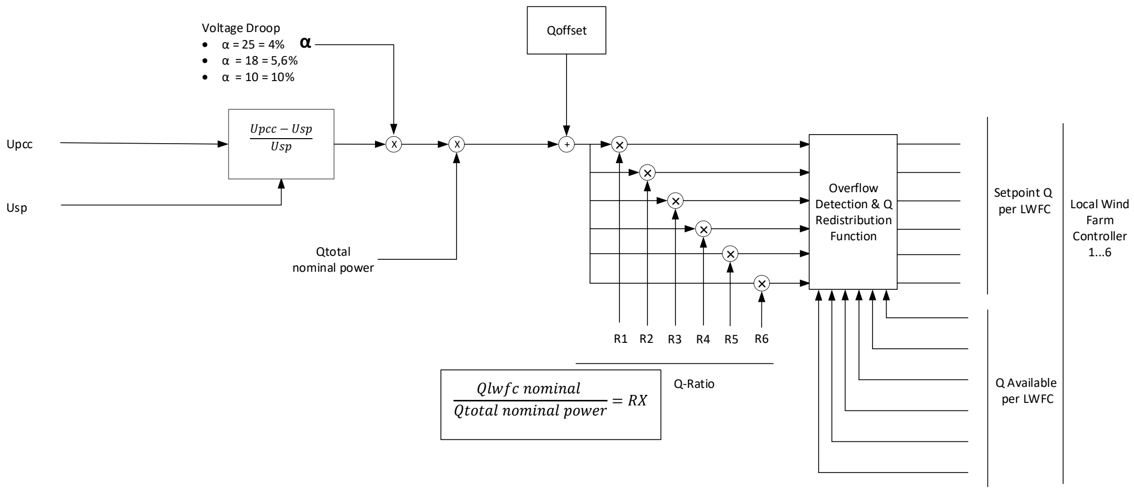

Figure 7 Block diagram voltage power control mode2

$$Qsetpoint\ LWFCx = \left(\alpha * \left(\frac{Usetpoint - Upcc}{Usetpoint} \right) * Qmax + Qoffset \right) RX$$

The alpha coëfficient represents the Droop percentage.

- 25 = 4%
- 18 = 5,6%
- 10 = 10%

The Q divider will use static ratio’s. RX is the factor that divides the calculated Q over the LWFC output.

The Overflow Detection and Redistribution Function will detect the event where a Qset-point will become bigger than the Q available per LWFC. The amount of Q unac-counted for will be redistributed over the other LWFC’s that still have an unaccounted amount of Q available.

2.4.3 Reactive Power Control Mode

This paragraph will provide an overview how the “Reactive Power Control Mode” is implemented in the CWFC. Beginning with this block diagram giving a schematic overview of the control mode.

The CWFC will measure the Reactive Power Q at the PCC. It will then be compared with the Q setpoint and corrective action will be taken by increasing or decreasing the reactive power per Local Wind Farm Controller.

2.4.3.1 Block Diagram Reactive Power Control Mode

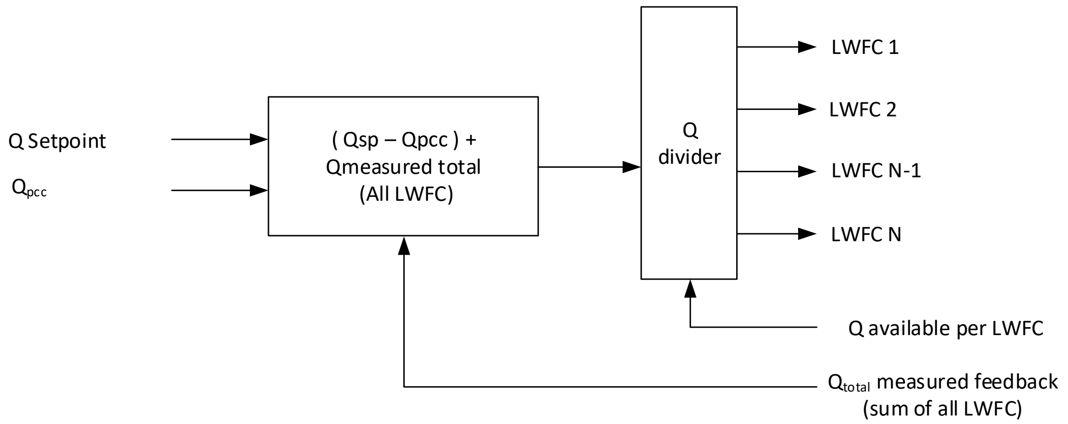

Figure 8 Block diagram reactive power control

2.4.4 Powerfactor Control Mode

This paragraph will provide an overview how the “Power Factor Control Mode” is implemented in the CWFC. Beginning with this block diagram giving a schematic overview of the control mode.

First step will be to determine the PF at PCC then it will be compare to the PF setpoint. The difference will be added/subtracted from the total PF calculated from the LWFC measurements. From this value the new Reactive Power Q will be determined.

2.4.4.1 Block Diagram Power Factor Control Mode

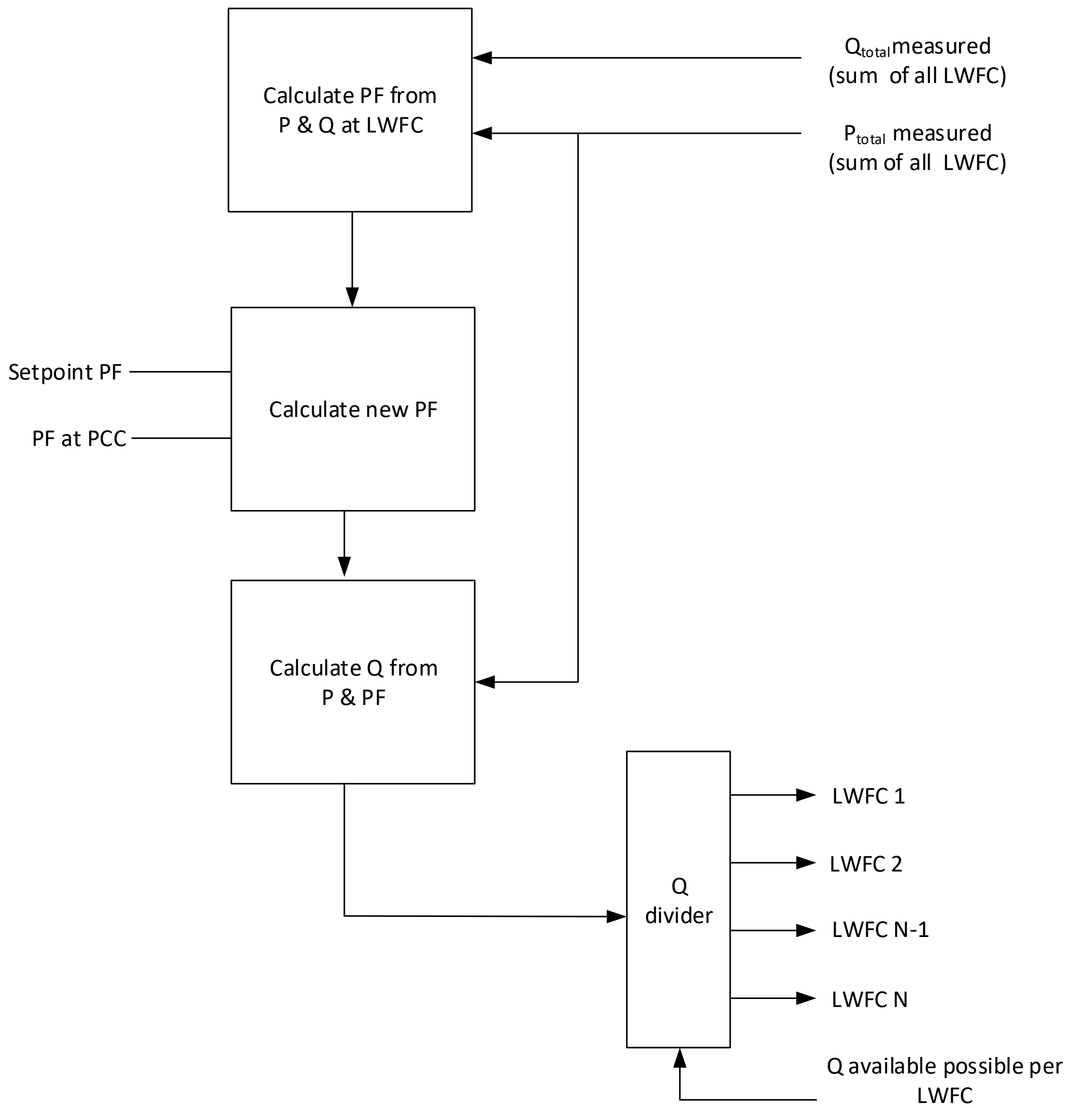

Figure 9 Block diagram power factor control

3 Hardware setup

The hardware for the central wind farm controller will exist of a remote terminal unit of the type RTU560 that is fitted with PLC functionality. In this chapter we will elaborate on the proposed hardware.

3.1 19" Swing frame rack for RTU 560

The RTU560 modules will be places in a 19" Rack 560SFR02. The rack has sufficient slots available and gives the opportunity to expand the system in the future.

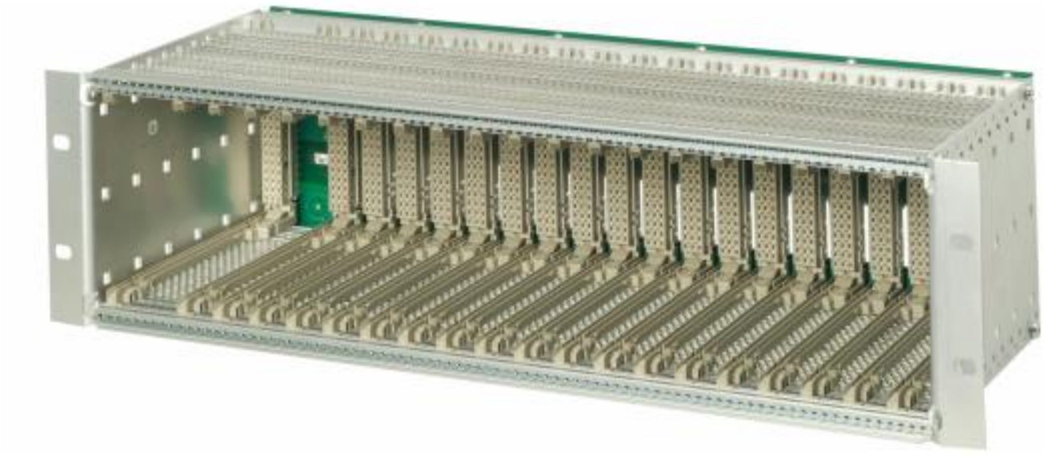

Figure 10 560SRF02 Swing rack frame

3.2 Communication units

This RTU560 module of type 560CMR01 will be used for communication purposes. The ethernet connections will be setup via this unit. Two ethernet connection are available per unit. Four units are accounted for in this design.

One of the four units will also have the PLC License to run the CWFC application.

Figure 11 560CMR01 Communications card

3.3 Power supply unit

This RTU560 module of type 560PSU02 will be used to power the RTU560.
The input range is 48 ... 220 V DC (-20%... +20%).
The output voltages are 5 and 48 VDC.

Figure 12 560PSU02 Power supply unit

3.4 Component overview

Item	Quantity	Part Number	Description
1	1	560SFR02 R0001	19” Rack Frame (Swing)
2	1	560BCU05R0001	Bus Connection Unit
3	4	560CMR01 R0001	Communication Unit
4	3		Rel. 12 Basic license open DP, SD
5	1		Rel. 12 HMI/PLC/Archives license open DP, SD
6	1	560PSU02 R0001	Power Supply Unit
7	15	560FPR01 R1002	Blanc cover plate
8	2	560BCU05R1002	BCU connectors

Tabel 1 Component Overview

4 Functionality

4.1 Setting the Setpoint Procedure

A setpoint is the level of system output which is desired. The regulator will steer the process output towards this value. The type of setpoint is determined by the type of “Reactive Power Control Mode”. The setpoint is entered via the CWFC “Configuration and Operation” menu.

When a new setpoint has been submitted, it will be checked for validity. When found to be valid, it will be implemented. Upon rejection, the user will be notified that the given setpoint is invalid.

nr.	Reactive Power Control Mode	Input	Remarks	Disturbance mode*
1	Voltage Control submode 1	Qref, Droop %	Automatic determinaton Uset = Upcc at Qpcc == Qref	yes
2	Voltage Control submode V2	Uset, Droop %		no
3	Power Factor Control	Cosine Phi		no
4	Reactive Power Control	Qset		no

* Disturbance mode: CWFC will hold reactive power for 15min.

Tabel 2 Input Overview per Reactive power control mode

4.2 Reactive Power Control Mode Selection

It will be possible to select another “Reactive Power Control Mode” in the CWFC “Configuration and Operation” menu.

4.3 PPA access

PPA’s will connect to the Enercon SCADA for monitoring data and Curtailment. They will no longer connect directly to the CWFC. As stated in req. 449 [1].

4.4 Local/Remote

Local/Remote functionality is available with regards to changing setpoint or reactive power control modes.

4.5 Communication with LWFC is down.

If the connection between CWFC and LWFC is lost. The standard course of action should be that het LWFC is stopped and the associated WEC units are stopped. Due to the fact that it is not possible to monitor/regulate the LWFC and associated WEC’s.

4.6 Shutting down the LWFC

The CWFC will be able to generate a stop signal to all or some LWFC.

5 HMI

Will be made available during the “Detail Design Phase”.

6 References

[1] Windpark Zeewolde B.V., "Vraagspecificatie deel 1 Technische Eisen 1.2," 2018.
[2] Windpark Zeewolde B.V., "Functional requirements Central Wind Farm Controller 1.0," 2018.
[3] Tennet B.V., "Data Exchange Wind Farms 5.3," 2016.

7 Tabel of Figures