P2029
Security of Supply in Curaçao's Electricity System

Analysis of Grid Events - 04.01.2021

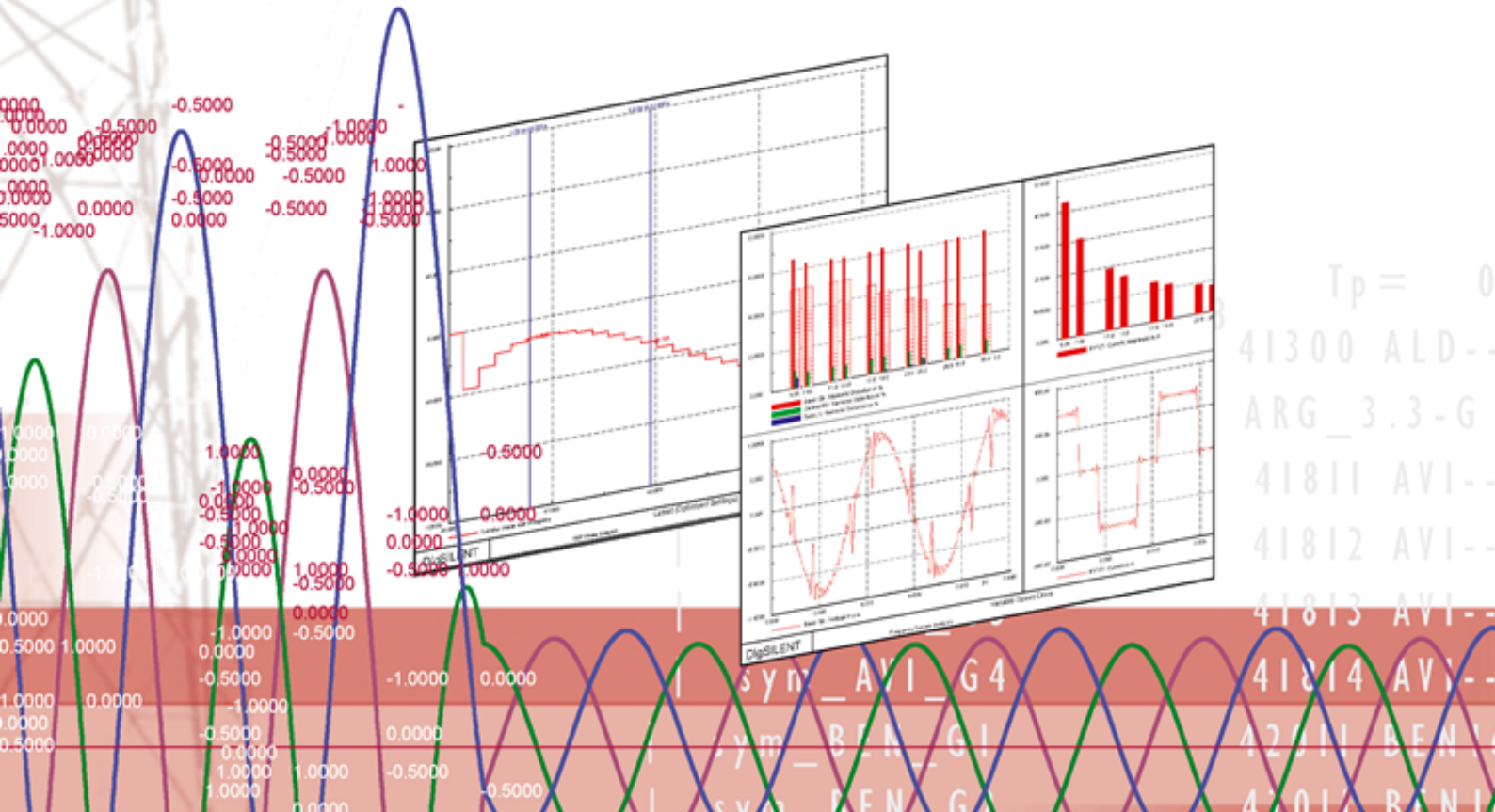
Prepared for:

Aqualectra

Curaçao - Netherland Antilles

Publisher:

DIgSILENT GmbH, February 2021



DIgSILENT GmbH
Heinrich-Hertz-Straße 9
D-72810 Gomaringen
Tel.: +49 7072 9168 - 0
Fax: +49 7072 9168- 88
http://www.digsilent.de

Please contact
José Gómez
T: +49 (0)7072 9188-84
j.gomez@digsilent.de

Document Revision History

Version	Status	File	Issued	Prepared by
01	Draft Version	P2029_Aqualectra_Event-Analysis-20210104_REPTRIP04_R01_V01.docx	05.02.2021	J. Gómez

Table of Contents

List of Abbreviations

PFM	DIgSILENT Monitoring System
SCADA	Supervisory Control and Data Acquisition
UFLS	Under-Frequency Load-Shedding

1 Introduction

On the 4th of January 2021, approximately at 14:13:23 hours, the power system of Aqualectra experienced a blackout. This report includes the analysis of the sequence of events and the results of the preliminary investigations.

2 Monitoring Systems

Several PFM monitoring systems are installed in the main substations of Aqualectra. However, some of them were not accessible and/or did not record the events of interest on the specific date subject of analysis. The following table shows an overview of their status at the time of the events:

Table 2-1: DIgSILENT Monitoring systems – Aqualectra - Curaçao

#	Substation	Type	Status (04.01.2021)
1	Isla NDPP	PFM300	Online, with recordings of the event available
2	Isla 66 kV	PFM300	Online, with recordings of the event available
3	Dokweg 1	PFM300	Online, but with no recordings at the time of the event
4	Dokweg 2	PFM300	Not accessible
5	Dokweg 66 kV	PFM300	Online, with recordings of the event available
6	Mundo Nobo	PFM2	Not accessible
7	Tera Cora	PFM2	Not accessible
8	Playa Canoa	PFM2	Not accessible

In addition, there is a SCADA system from Aqualectra which records measurements from multiple locations in the power system.

Annex A includes detailed information of the measurement signals available.

3 Recordings

The following recordings have been used in the analysis of the events:

Table 3-1: Recordings used in the analysis of the events

File Name	Source	Resolution	Duration
Generation 2021 jan.xlsx [1]	SCADA	1-minute	24/12/2020 00:00 22/01/2021 23:59
Load 2021 jan.xlsx [2]	SCADA	1-minute	24/12/2020 00:00 22/01/2021 23:59
Monitor_2020.01.04 23.59.59.dat [3]	PFM300 – Dokweg 66 kV	1-second	04/01/2021 00:00:00.000 05/01/2021 00:00:00.000
RMS_2020.01.04 14.13.23.dat [4]	PFM300 – Dokweg 66 kV	20-milisecond	04/01/2021 14:12:23 04/01/2021 14:26:29
Monitor_2020.01.04 23.59.59.dat [5]	PFM300 – Isla 66 kV	1-second	04/01/2021 00:00:00.000 05/01/2021 00:00:00.000
RMS_2020.01.04 14.13.23.dat [6]	PFM300 – Isla 66 kV	20-milisecond	04/01/2021 14:12:23 04/01/2021 14:26:29
Monitor_2020.01.04 23.59.59.dat [7]	PFM300 – Isla NDPP	1-second	04/01/2021 00:00:00.000 05/01/2021 00:00:00.000
RMS_2020.01.04 14.13.23.dat [8]	PFM300 – Isla NDPP	20-milisecond	04/01/2021 14:12:23 04/01/2021 14:26:29

4 Timeline of Events

The generation dispatch in the power system at 14:10:00 hours, prior to the blackout (14:13:23 hours), is shown in Table 4-1. The total demand at this time is 78,8 MW. Power flow across line Dokweg 66kV-Parera is zero, hence it is assumed that this line is not in operation. Power flow across line Dokweg 66kV-Isla 66 kV is 63,3 MW, which seems to be the only line connecting Dokweg 2A and 2B power plants to the rest of Aqualectra power system.

Table 4-1: Generation dispatch at 14:10:00 hours

Power Plant	Unit	Output Power [MW]
Dokweg 2A	DG09	30,7
	DG10	
	DG11	
	DG12	
Dokweg 2B	DG15	16,8
	DG16	
Dokweg 2B	DG13	n/a
	DG14	n/a
NDPP	DE1	0 (offline)
	DE2	0 (offline)
	DE3	0 (offline)
	DE4	4,9
Dokweg1	DG1	n/a
	DG2	n/a
	DG3	n/a
	DG4	n/a
	DG5	n/a
	DG6	n/a
	DG7	n/a
Mundo Nobo	GT2	25,2
BOO	-	16,8
Wind Farm Playa Canoa	-	0 (offline)
Wind Farm Tera Cora 1	-	0 (offline)
Wind Farm Tera Cora 2	-	0 (offline)

Based on the available recordings from the PFM and the SCADA, the sequence of events is shown in Table 4-2. Annexes B and C include dedicated plots of the recordings used for the analysis of the events.

Table 4-2: Timeline of events

Time	Event
12:00:00 - 13:35:00	Power system operates stable at nominal frequency and with voltages close to nominal values (1,00-1,04 p.u.). Output power from diesel units in Dokweg 2A and 2B shows continuous modulation, which suggests that these power plants are operating in isochronous mode.
13:35:00 – 14:13:23	Power flow across line Dokweg 66kV-Isla 66 kV gradually increases from 60 MW up to 65 MW, which is consistent with an increase in the power production in Dokweg 2A and 2B.
14:13:23	Trip of line Dokweg 66kV-Isla 66 kV when the power flow is 65 MW. Subsequent investigations [9] have determined that the root cause is the activation of the overcurrent protection P139 in this line, adjusted at 0,88*In, which is consistent with the power flow measured at the line right before tripping. These settings trip the line when the current exceeds 88% of the rated current, i.e. before reaching 100% loading of the line. More information about the protection settings is included in Annex D. Since this is the only line connecting Dokweg 2A and 2B power plants to the rest of Aqualectra power system, both systems separate and different frequencies are observed: fast increase in the Dokweg 2A and 2B side, and fast decay in Isla 66 kV and Isla NDPP. As a result, UFLS is triggered and substantial loss of demand is observed. Despite this, the system is not capable of stabilising and frequency keeps decreasing, followed by a system blackout.
16:28:14 – 23:59:59	Power restoration starts at 16:28:14 hours. At 16:42:46, frequency reaches nominal frequency and it gradually stabilises towards steady-state operation. Voltage at substation Isla 66 kV stabilises above nominal voltage (1,13 – 1,15 p.u.)

5 Conclusions and Recommendations

The blackout on the 4th of January of 2021 shares similar root causes and consequences with the blackout experienced on the 10th and 12th of December of 2020, for which dedicated investigation reports are also available [10] [11].

The analysis of the events reveals that the main cause leading to the blackout is the activation of the overcurrent protection of the line Dokweg 66kV-Isla 66 kV, currently adjusted at 0,88*In. This setting does not allow loading of the line above 88% of the rated current.

It is recommended to review these protection settings in order to verify if there is any justified limitation that prevents that, in steady-state conditions, rated current can flow continuously through the line. Moreover, this review should be extended to the rest of protection functions in the line Dokweg 66kV-Isla 66 kV, as well as the other transmission lines in Aqualectra power system.

Prior to the blackout, line Dokweg 66kV-Parera was out-of-service, hence all generation from Dokweg 2 power plant was being exported through line Dokweg 66kV-Isla 66 kV. This operation has revealed as not N-1 secure with very critical consequences for system stability. Therefore, it is recommended to review operational practices in order to define a maximum power export from Dokweg 2 power plant, especially when line Dokweg 66kV-Parera is out-of-service.

6 References

[1] Aqualectra, "Generation 2021 jan.xlsx".

[2] Aqualectra, "Load 2021 jan.xlsx".

[3] "Dokweg 66 kV - Monitor_2020.01.04 23.59.59.dat".

[4] "Dokweg 66 kV - RMS_2020.01.04 14.13.23.dat".

[5] "Isla 66 kV - Monitor_2020.01.04 23.59.59.dat".

[6] "Isla 66 kV - RMS_2020.01.04 14.13.23.dat".

[7] "Isla NDPP - Monitor_2020.01.04 23.59.59.dat".

[8] "Isla NDPP - RMS_2020.01.04 14.13.23.dat".

[9] DIgSILENT, "Email with Subject: Protection settings 66 kV Isla - 66 kV Dokweg," 14.01.2021 12:45.

[10] DIgSILENT, "P2029_Aqualectra_Event-Analysis-20201210_REPTRIP02_R01_V02.pdf".

[11] DIgSILENT, "P2029_Aqualectra_Event-Analysis-20201212_REPTRIP03_R01_V01.pdf".

7 Annex A: Measurement Signals

Table 7-1: Measurement signals – PFM at Dokweg 66 kV

Signal	Enabled	Feeder connection	Location
BUS-A	X		DKW66/BB1
BUS-B	X		DKW66/BB2
Spare VT		-	-
Bus coupler	X	-	DKW66/CB0
BOO	X	No cable connected yet (spare)	-
NDPP	X	No cable connected yet (spare)	-
Wartsila	X	Feeder F03	66/11 kV Transformer DW2SUT4 (Dokweg 2B - Units 15 and 16)
Isla 1	X	Feeder F04	ISLA-Dokweg2
Dokweg II-T1	X	Feeder F05	66/11 kV Transformer DW2SUT1 (Dokweg 2A - Units 09 and 10)
Parera	X	Feeder F07	Dokweg2-Parera
Weis	X	No cable connected yet (spare)	-
Nijlweg	X	No cable connected yet (spare)	-
Spare CT 1		Feeder F10	66/11 kV Transformer DW2SUT3 (Dokweg 2B - Units 13 and 14)
Isla 2	X	No cable connected yet (spare)	-
Dokweg II-T2	X	Feeder F12	66/11 kV Transformer DW2SUT2 (Dokweg 2A - Units 11 and 12)
Spare CT 2		-	-
Spare CT 3		-	-
Spare CT 4		-	-
Digital Input 1	X	-	-

Table 7-2: Measurement signals – PFM at Isla 66 kV

Signal	Enabled	Feeder connection	Location
Dwarskoppelveld sec.	X	1	ISL 66/CB.L0
spare		2	-
Weis	X	3	ISLA-Weis
BOO-I	X	4	66/30 kV Transformer BOO1
Parera-I	X	5	ISLA-Parera
NDPP-I	X	6	66/11 kV Transformer NDPP1 (Units DE1 and DE2)
Langskoppelveld sec.-I	X	7	-
Langskoppelveld sec.-II	X	8	-
Nijlweg	X	9	ISLA-Nijlweg
BOO-II	X	10	66/30 kV Transformer BOO2

Signal	Enabled	Feeder connection	Location
Parera-II	X	11	ISLA-Dokweg2
NDPP-II	X	12	66/11 kV Transformer NDPP2 (Units DE3 and DE4)
Dwarskoppelveld sec.-II	X	13	ISL 66/CB.R0

Table 7-3: Measurement signals – PFM at Isla NDPP

Signal	Enabled	Feeder connection	Location
Generator 4	x	K08	DE4
Generator 3	x	K07	DE3
Generator 2	x	K04	DE2
Generator 1	x	K03	DE1

Table 7-4: Measurement signals – SCADA

Signal	Voltage	Frequency	Active Power	Reactive Power	Location
ISL F06			x	x	NDPP1 (DE1 and DE2)
ISL F12			x	x	NDPP2 (DE3 and DE4)
DK2 F06	x		x	x	-
DK2A K00	x	x			Dokweg 2A plant BB1/BB2
DK2B K00	x	x			Dokweg 2B plant BB1/BB2
TER H02			x	x	Tera Cora-Windfarm Tera Cora 1
TER H08			x	x	Tera Cora-Windfarm Tera Cora 2
BRG H04			x	x	Brievengat-Windfarm Playa Canoa
BRG H01	x				Brievengat 30kV BB1/BB2
PSA H01	x				Parasasa 30kV BB1/BB2
JPL H01	x				Julianaplein 30kV BB1/BB2
MNE H03			x	x	GT2SUT

8 Annex B: PFM Recordings

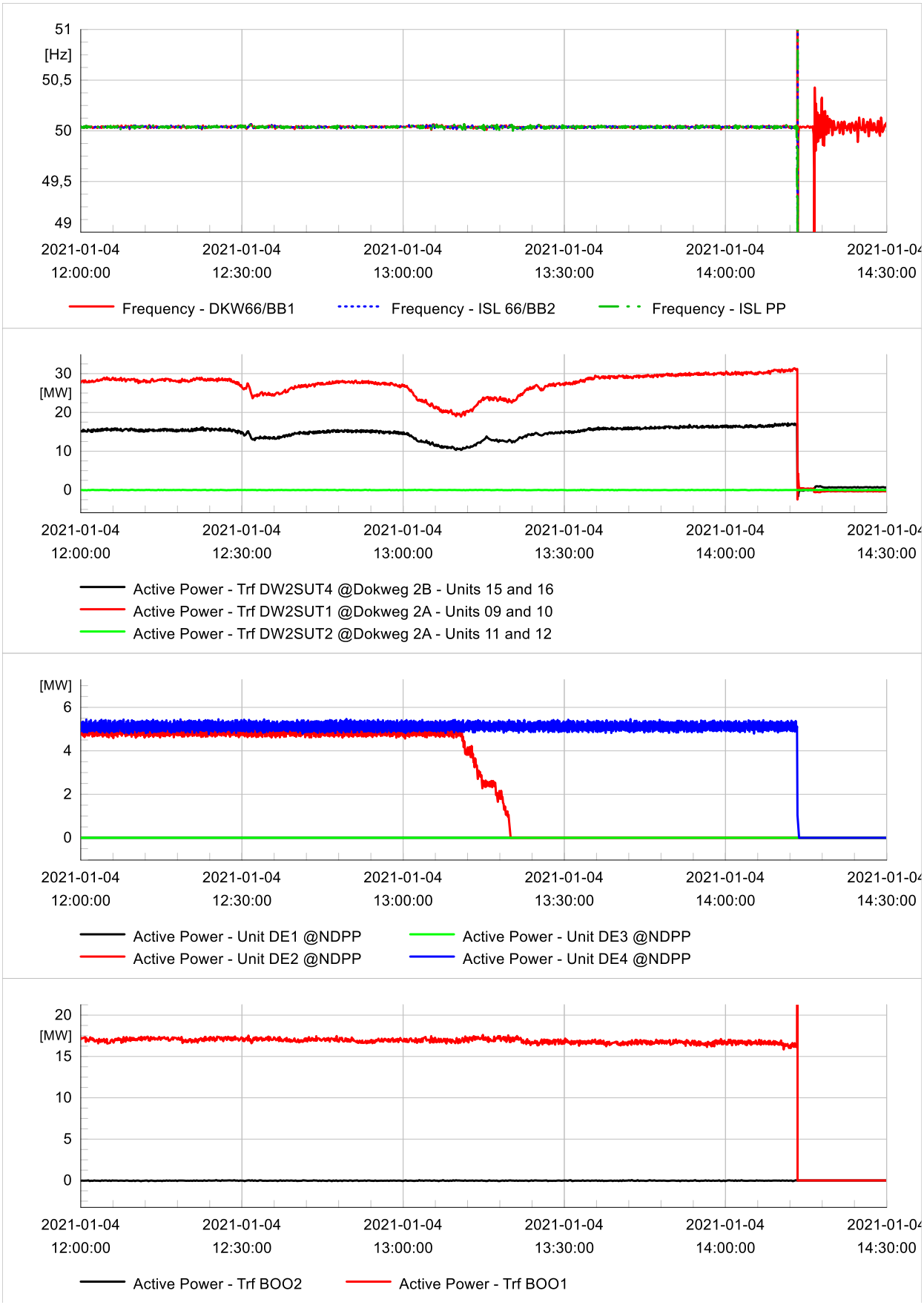


Figure 1: PFM Recordings - Frequency and Active Power – From 12:00:00 to 14:30:00 hours

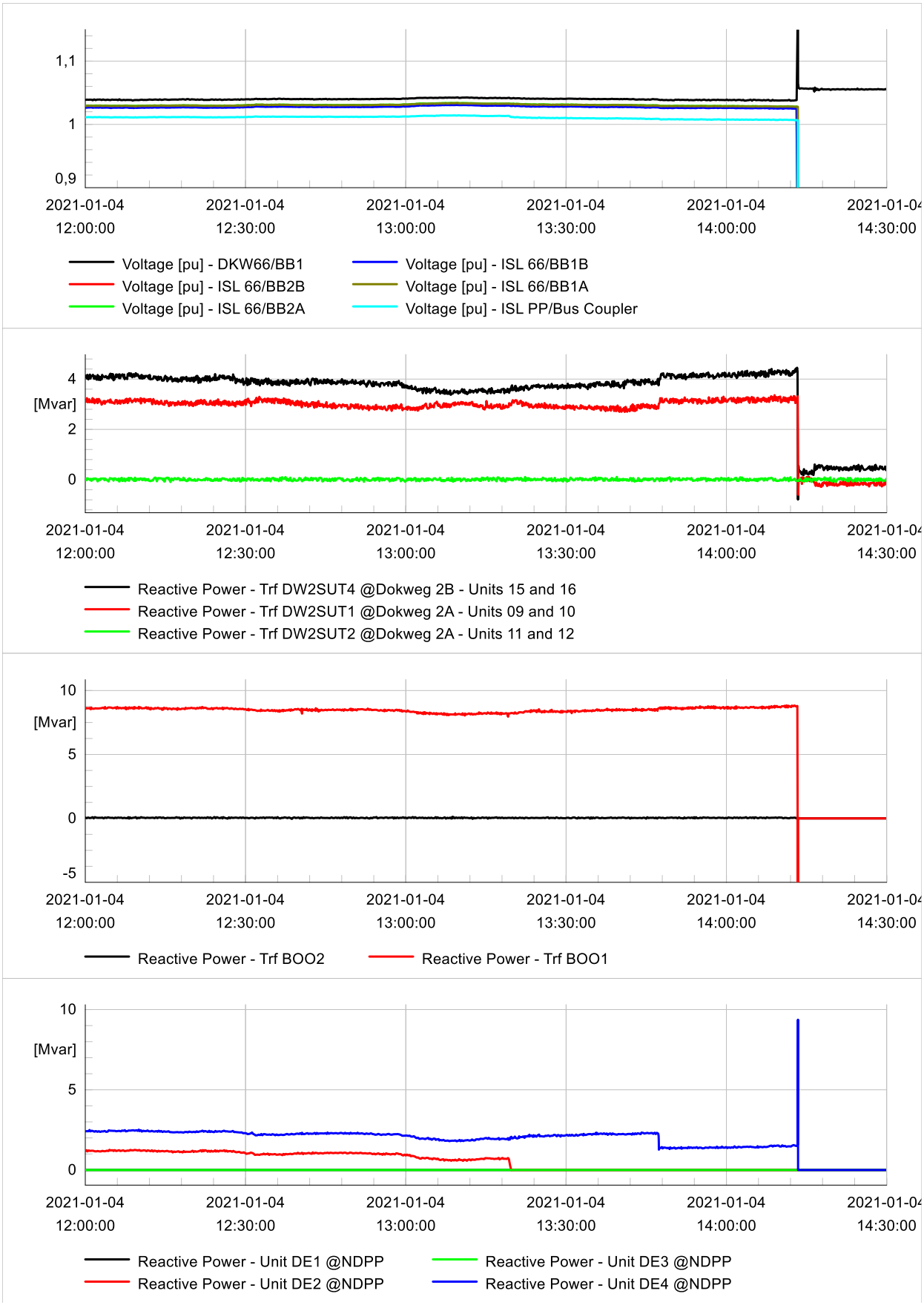


Figure 2: PFM Recordings - Voltage and Reactive Power – From 12:00:00 to 14:30:00 hours

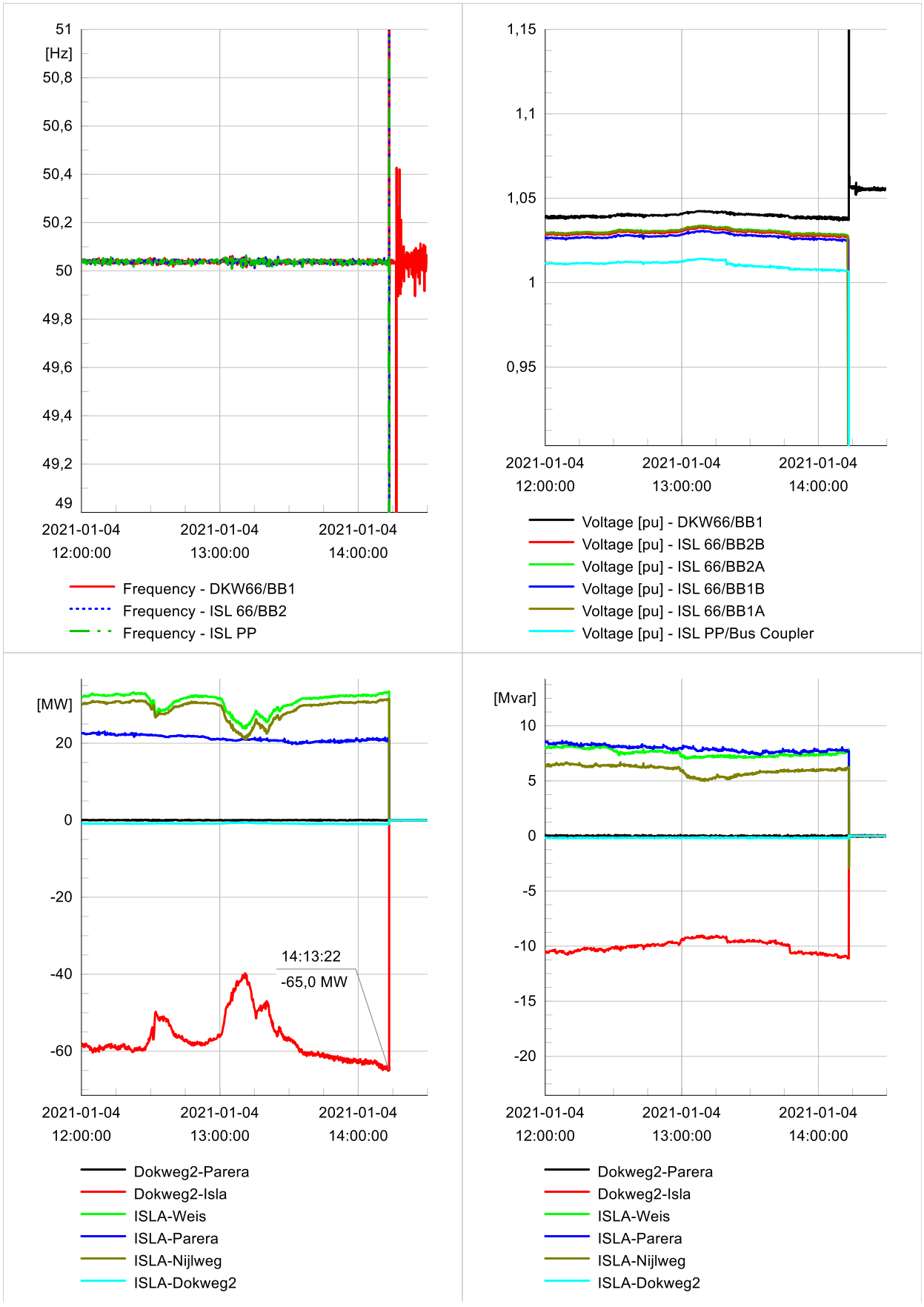


Figure 3: PFM Recordings – Frequency, Voltage and Power across Lines– From 12:00:00 to 14:30:00 hours

Figure 4: PFM Recordings - Frequency and Active Power – From 14:13:15 to 14:13:35 hours

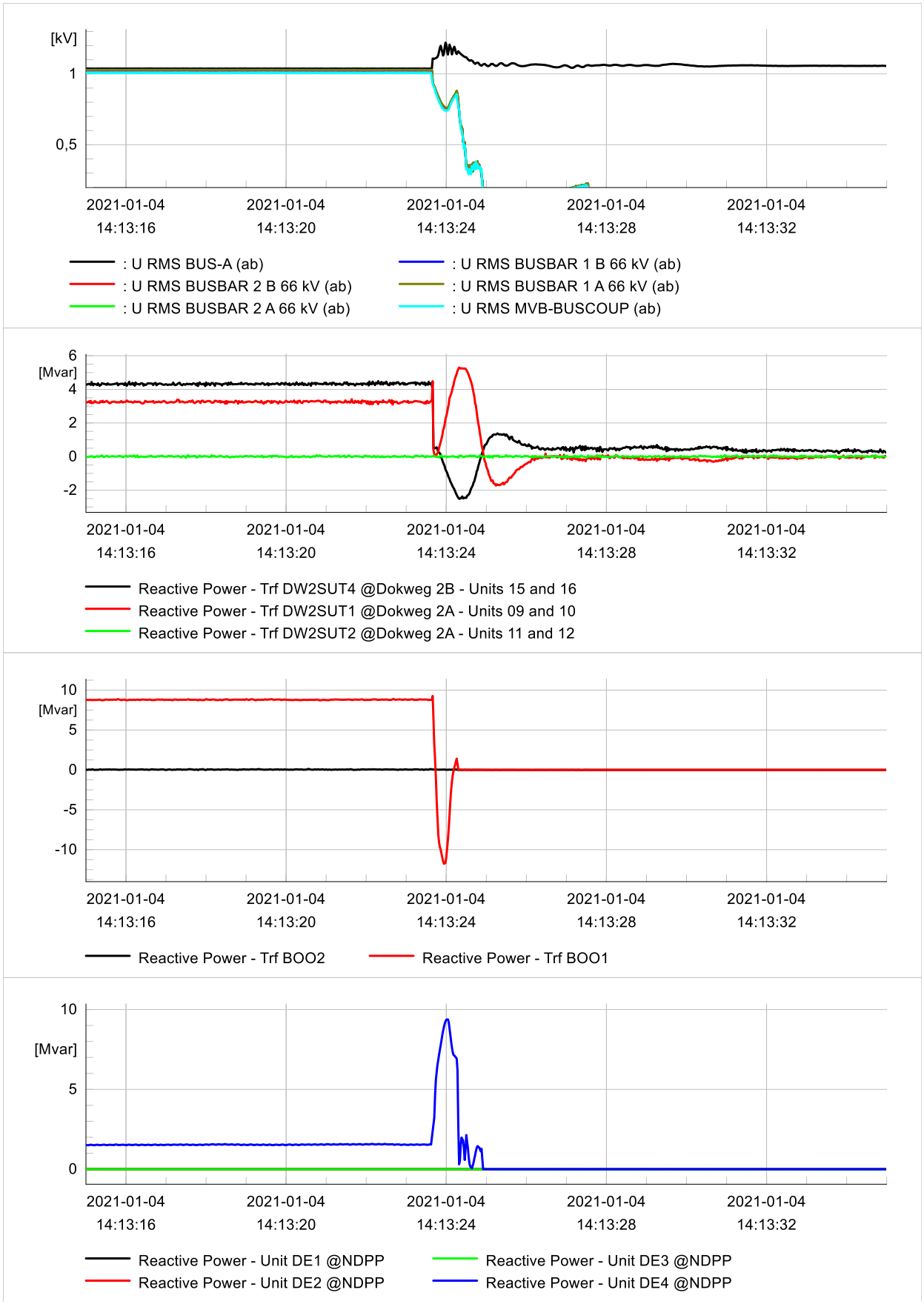


Figure 5: PFM Recordings - Voltage and Reactive Power – From 14:13:15 to 14:13:35 hours

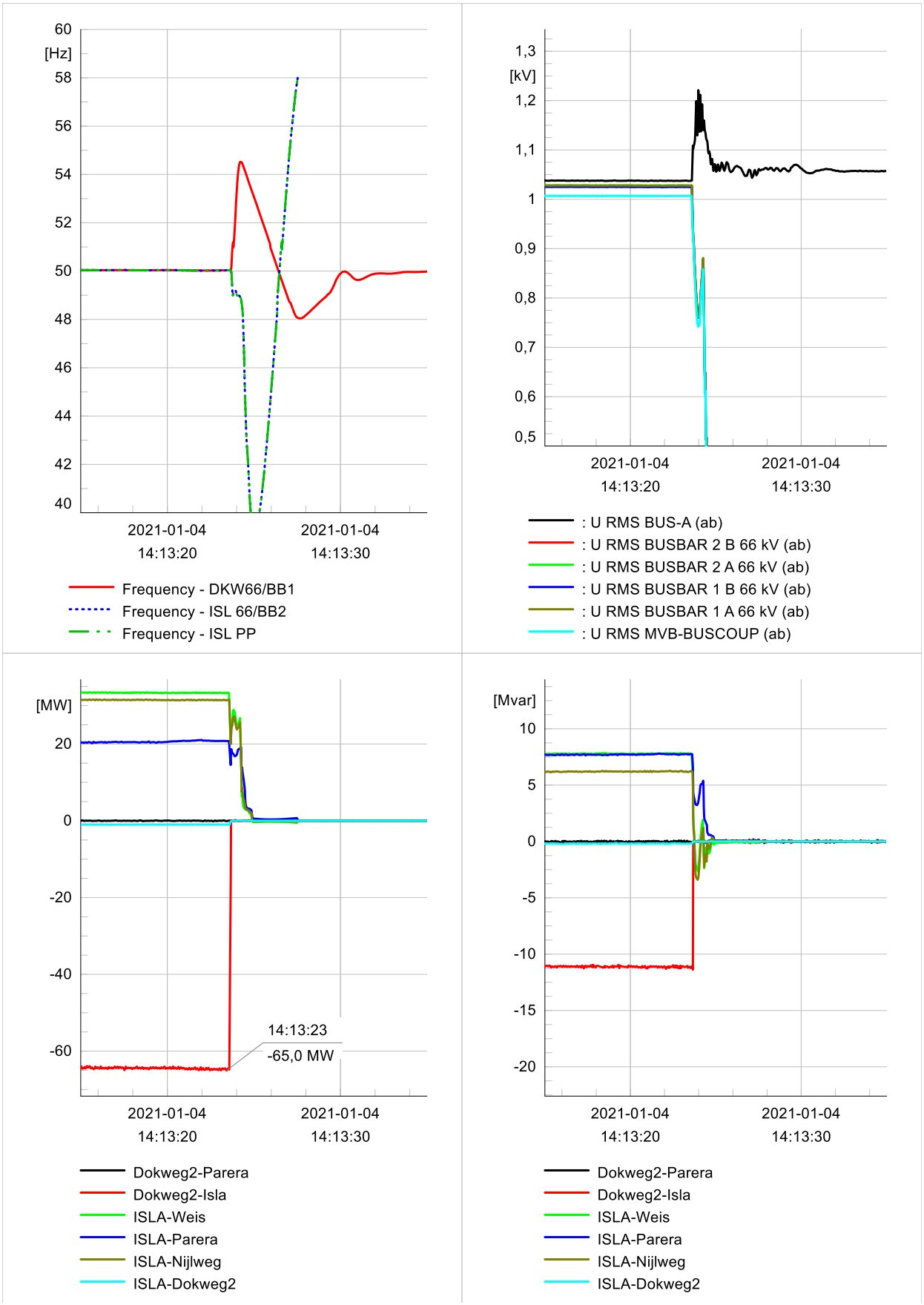


Figure 6: PFM Recordings – Frequency, Voltage and Power across Lines– From 14:13:15 to 14:13:35 hours

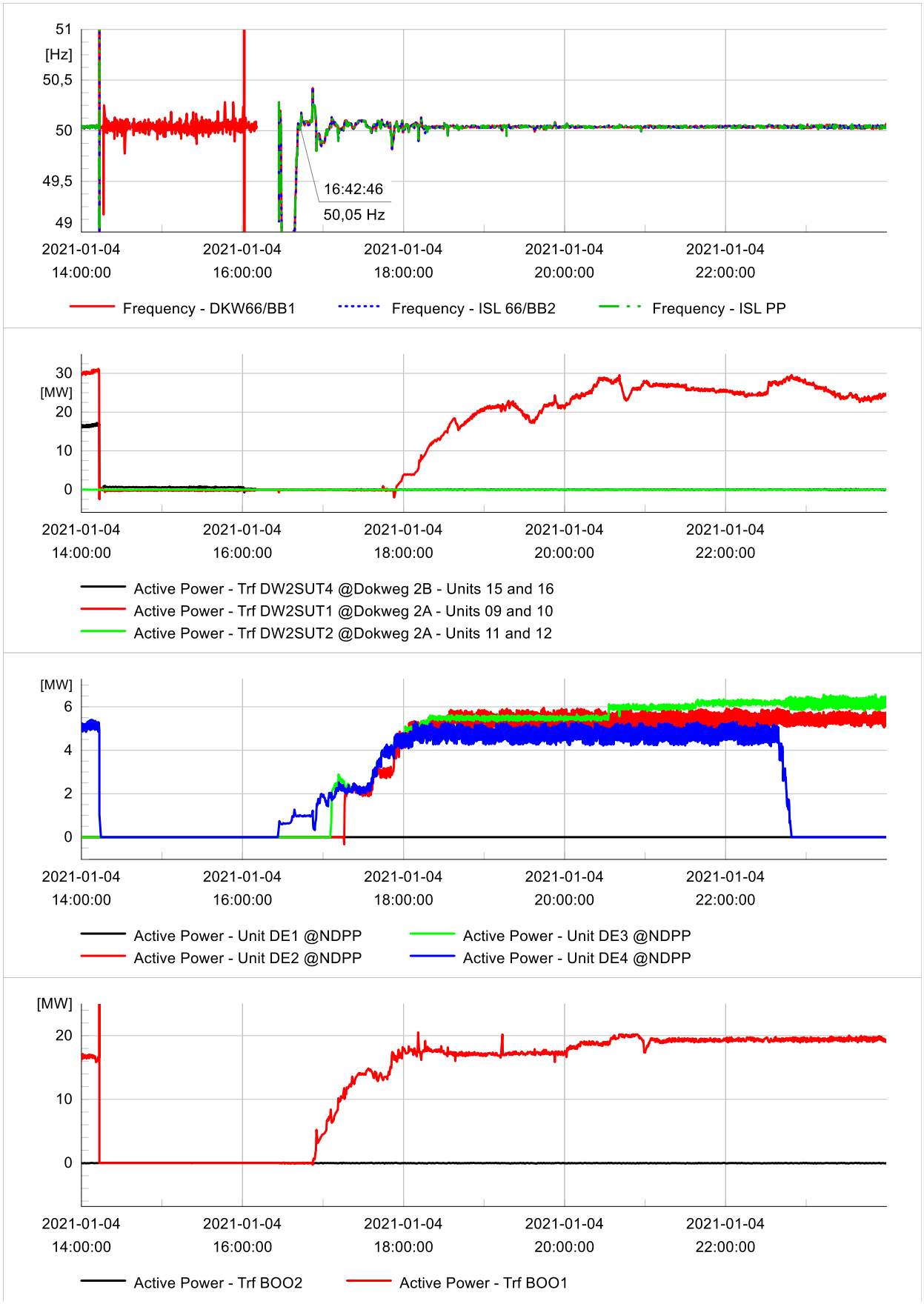


Figure 7: PFM Recordings - Frequency and Active Power – From 14:00:00 to 23:59:59 hours

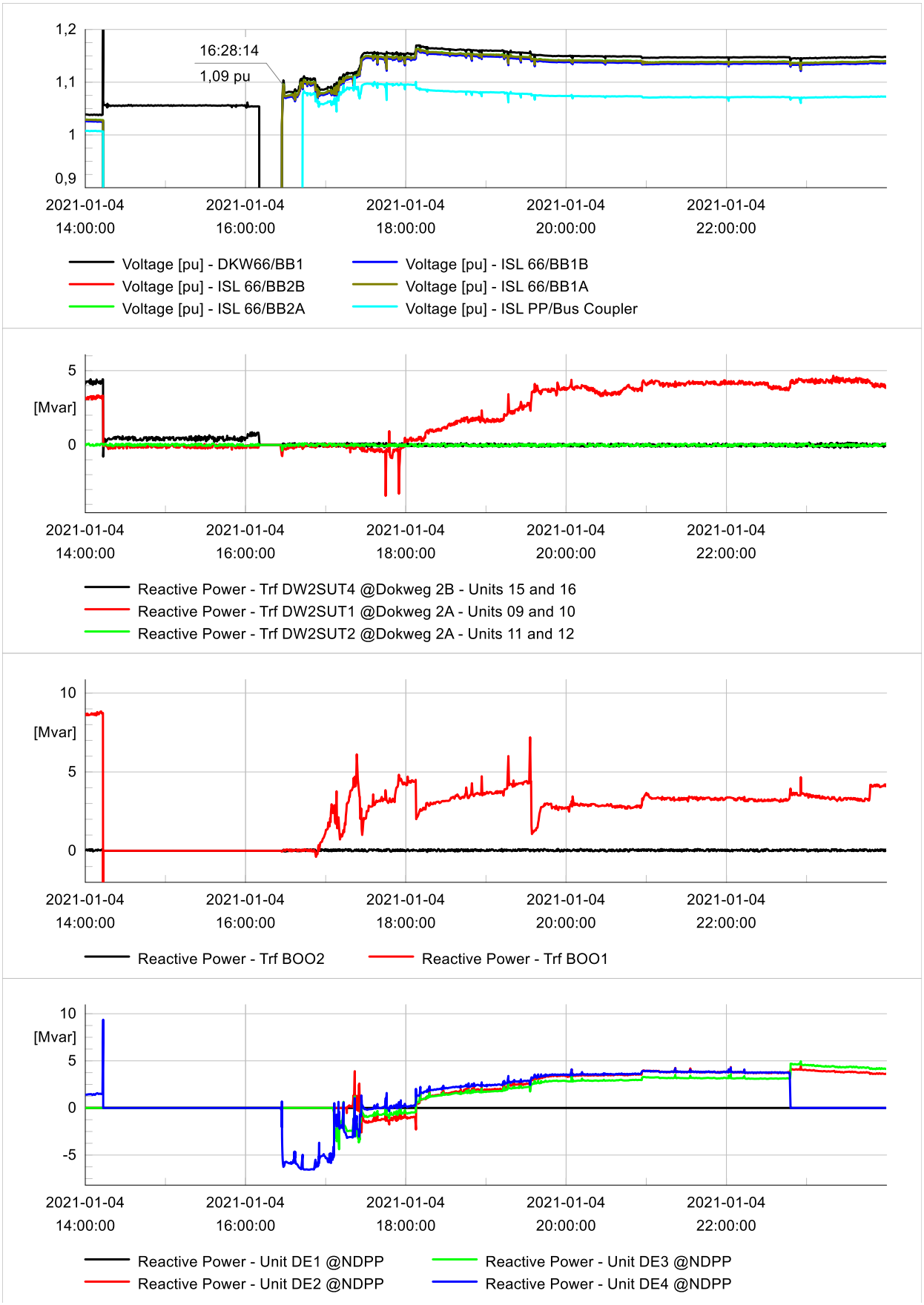


Figure 8: PFM Recordings - Voltage and Reactive Power – From 14:00:00 to 23:59:59 hours

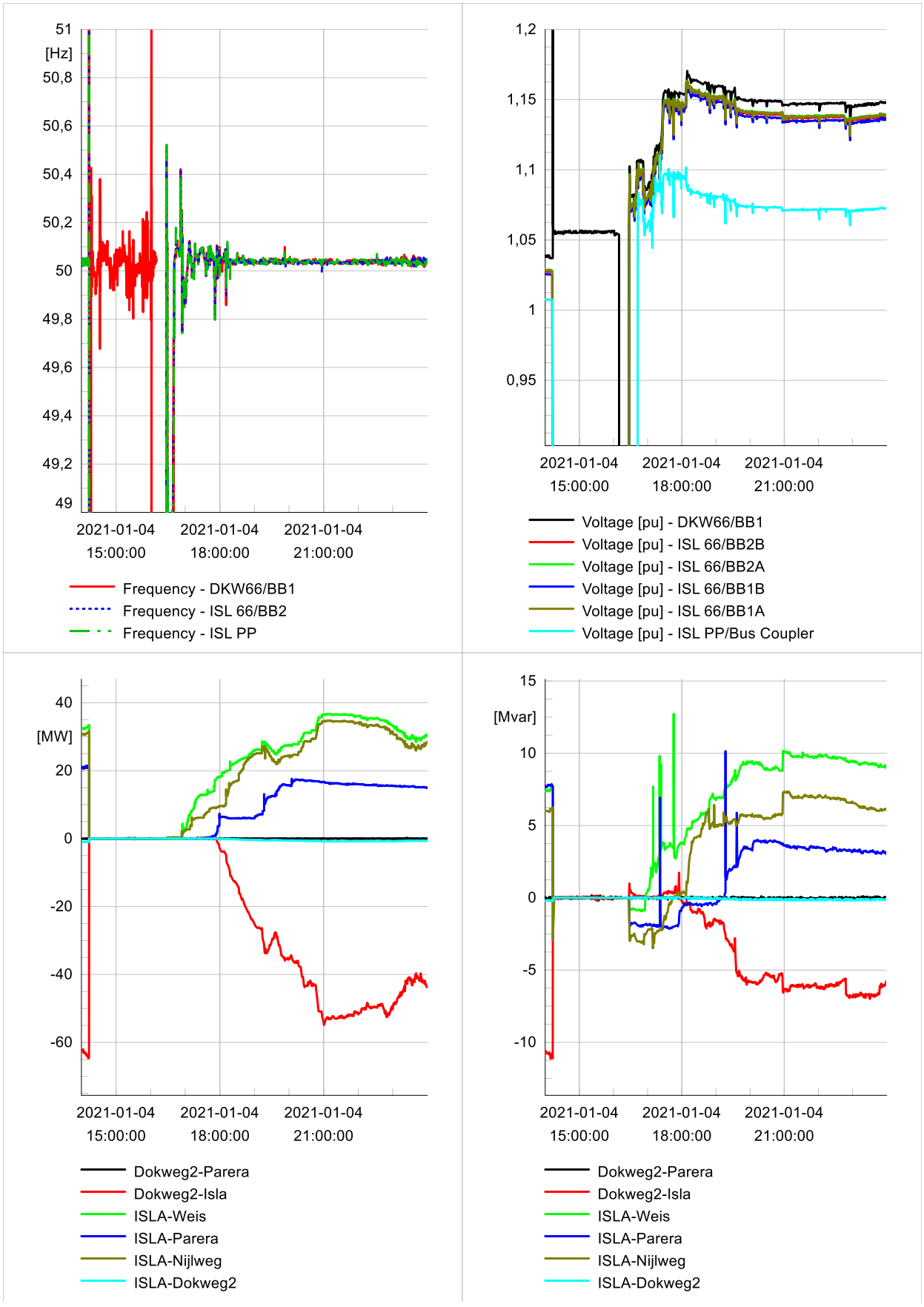


Figure 9: PFM Recordings – Frequency, Voltage and Power across Lines– From 14:00:00 to 23:59:59 hours

9 Annex C: SCADA Recordings

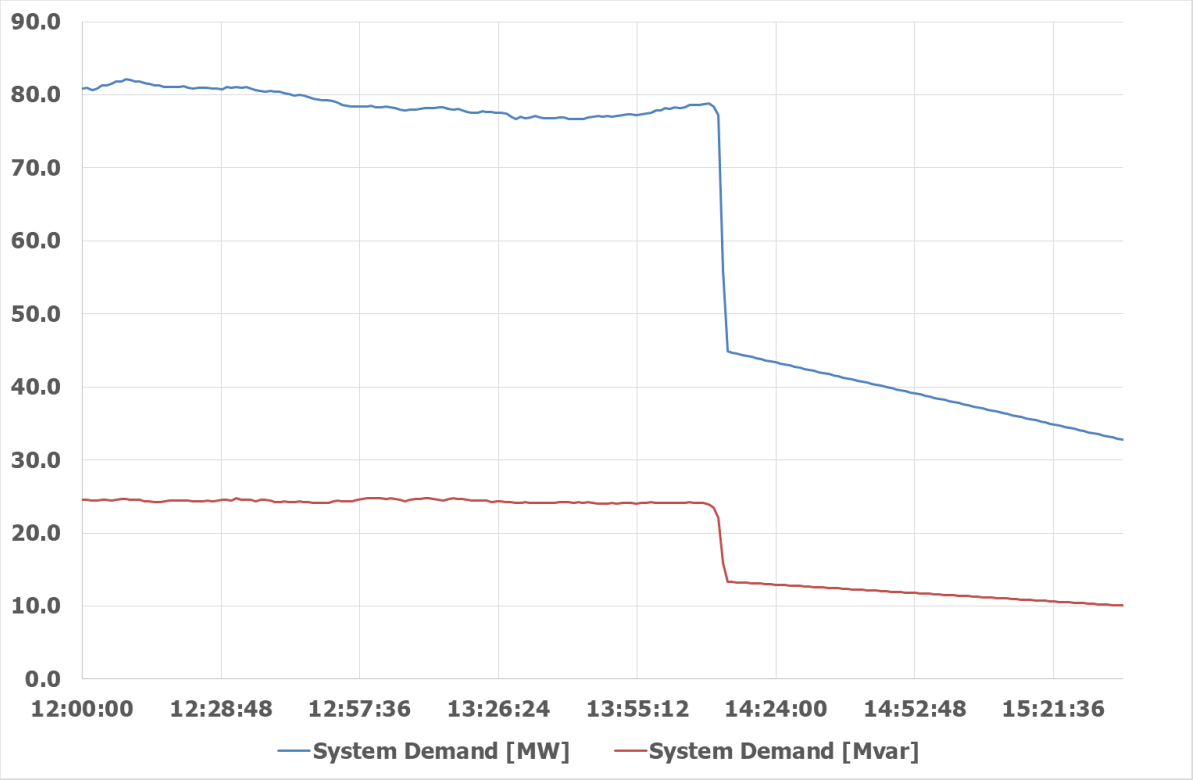


Figure 10: SCADA Recordings – System Demand– From 12:00:00 to 15:30:00 hours

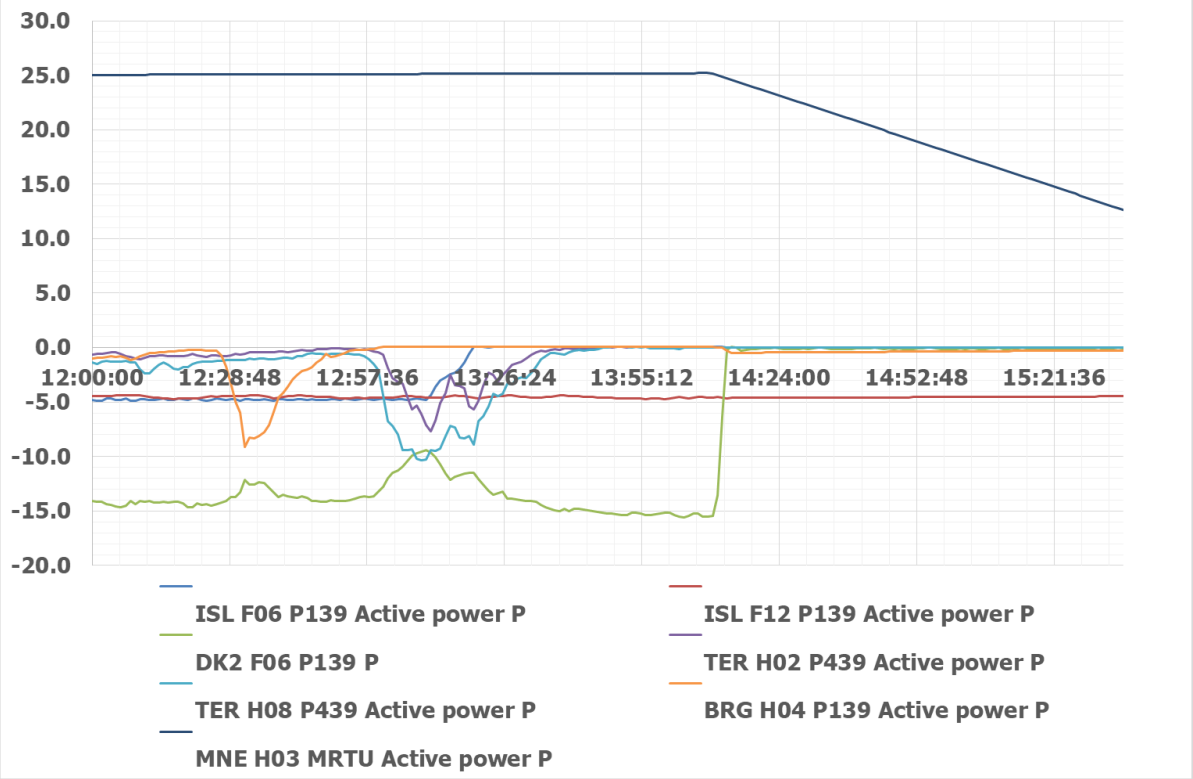


Figure 11: SCADA Recordings – Active Power Measurements [MW]– From 12:00:00 to 15:30:00 hours

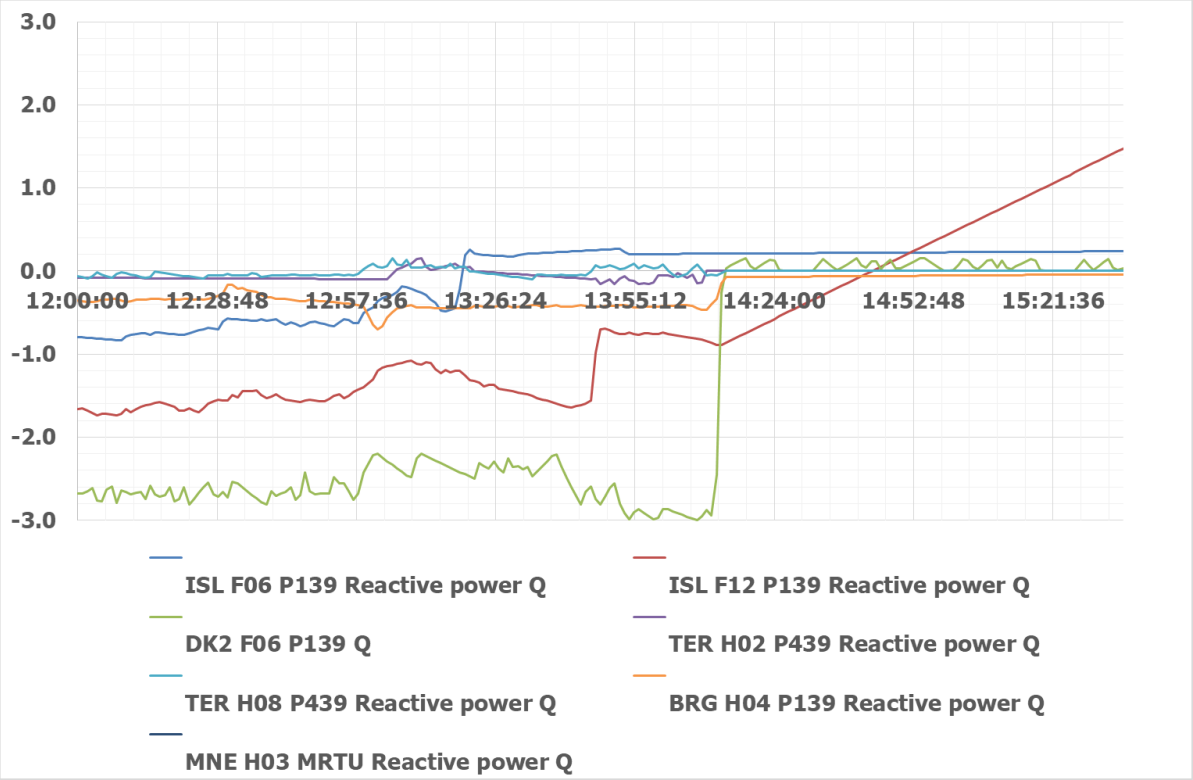


Figure 12: SCADA Recordings – Reactive Power Measurements [Mvar]– From 12:00:00 to 15:30:00 hours

10 Annex D: Overcurrent Protection (P139) Settings in Line Dokweg 66kV-Isla 66 kV

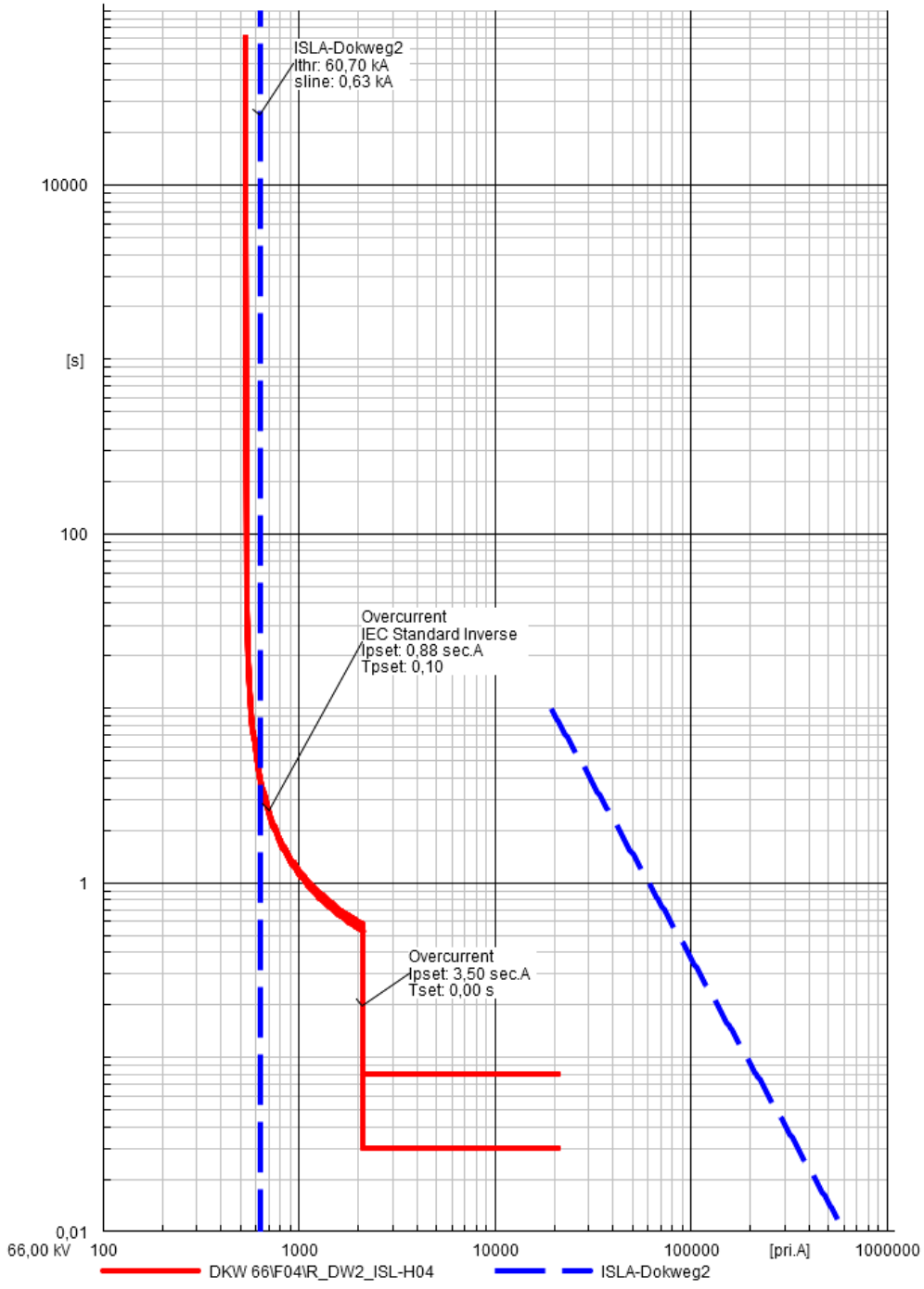


Figure 13: Overcurrent Protection (P139) Settings in Line Dokweg 66kV-Isla 66 kV [9]