

P2029

Security of Supply in Curaçao's Electricity System

Analysis of Grid Events - 10.12.2020

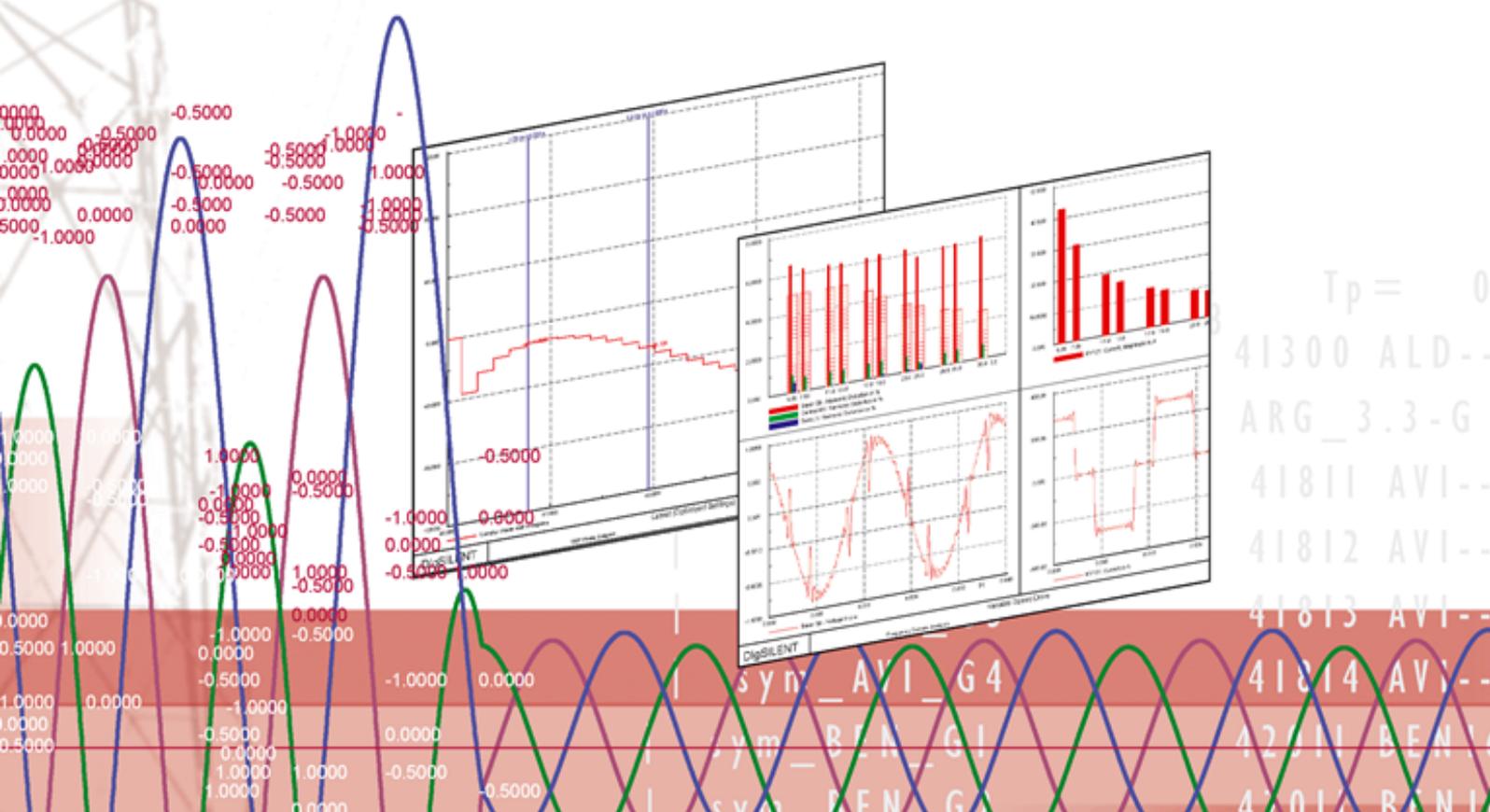
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DIgSILENT GmbH

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

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List of Abbreviations

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

1 Introduction

On the 10th of December 2020, approximately at 15:14:35 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 are not accessible and/or did not record the events of interest on the specific data subject to 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 (10.12.2020)
1	Isla NDPP	PFM300	Online, with recordings of the events available
2	Isla 66 kV	PFM300	Online, with recordings of the events available
3	Dokweg 1	PFM300	Not accessible
4	Dokweg 2	PFM300	Not accessible
5	Dokweg 66 kV	PFM300	Online, with recordings of the events 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 from 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 202011_202012_1min.xlsx [1]	SCADA	1-minute	24/11/2020 00:00 12/11/2020 03:45
Load 202011_202012_1min.xlsx [2]	SCADA	1-minute	24/11/2020 00:00 12/11/2020 03:45
Monitor_2020.12.10 23.59.59.dat [3]	PFM300 – Dokweg 66 kV	1-second	10/12/2020 00:00:00.000 11/12/2020 00:00:00.000
RMS_2020.12.10 15.14.35.dat [4]	PFM300 – Dokweg 66 kV	20-millisecond	10/12/2020 15:13:35.440 10/12/2020 15:14:35.440
Monitor_2020.12.10 23.59.59.dat [5]	PFM300 – Isla 66 kV	1-second	10/12/2020 00:00:00.000 11/12/2020 00:00:00.000
RMS_2020.12.10 15.14.35.dat [6]	PFM300 – Isla 66 kV	20-millisecond	10/12/2020 15:13:35.440 10/12/2020 15:14:35.440
Monitor_2020.12.10 23.59.59.dat [7]	PFM300 – Isla NDPP	1-second	10/12/2020 00:00:00.000 11/12/2020 00:00:00.000
RMS_2020.12.10 15.14.35.dat [8]	PFM300 – Isla NDPP	20-millisecond	10/12/2020 15:13:35.440 10/12/2020 15:14:35.440

4 Timeline of Events

The generation dispatch in the power system at 15:11:00 hours, prior to the blackout (15:14:35 hours), is shown in Table 4-1. The total demand at this time is 90,9 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 60,6 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 15:11:00 hours

Power Plant	Units	Output Power [MW]
Dokweg 2A	DG09	24,6
	DG10	
	DG11	
	DG12	
Dokweg 2B	DG15	18,2
	DG16	
Dokweg 2B	DG13	n/a
	DG14	n/a
NDPP	DE1	0 (offline)
	DE2	4,9
	DE3	5,0
	DE4	5,1
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	5,3
BOO	-	n/a (online)
Wind Farm Playa Canoa	-	3,6
Wind Farm Tera Cora 1	-	4,0
Wind Farm Tera Cora 2	-	8,6

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
14:30:00 - 15:12:00	<p>Power system operates stable at nominal frequency and with voltages close to nominal values (0,98-1,04 p.u.).</p> <p>Output power from diesel units in Dokweg 2A and 2B increase gradually during this time, following the slow increase in system demand. This continuous modulation suggests that these power plants are operating in isochronous mode.</p>
15:12:00 – 15:14:35	<p>Diesel units in Dokweg 2B start reducing gradually their output power, while diesel units in Dokweg 2A start increasing it correspondingly.</p> <p>It is not clear the root cause for this change in the trend observed before. It could be due to a manual changeover in the diesel units in Dokweg 2B from isochronous mode to constant power.</p>
15:14:35	<p>Trip of line Dokweg 66kV-Isla 66 kV when the power flow is 62 MW. The root cause is the activation of the overcurrent protection P139 in this line, adjusted at $0,88 \cdot I_n$ (~63 MW), which is consistent with the power flow measured at the line right before tripping [9]. 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.</p> <p>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.</p> <p>As a result, UFLS is triggered and substantial loss of demand is observed. Despite this, system is not capable of stabilising and frequency keeps decreasing, followed by a system blackout.</p>

5 Conclusions and Recommendations

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.

Moreover, 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 202011_202012_1min.xlsx".
- [2] Aqualectra, "Load 202011_202012_1min.xlsx".
- [3] "Dokweg 66 kV - Monitor_2020.12.10 23.59.59.dat".
- [4] "Dokweg 66kV - RMS_2020.12.10 15.14.35.dat".
- [5] "Isla 66 kV - Monitor_2020.12.10 23.59.59.dat".
- [6] "Isla 66kV - RMS_2020.12.10 15.14.35.dat".
- [7] "Isla NDPP - Monitor_2020.12.10 23.59.59.dat".
- [8] "Isla NDPP - RMS_2020.12.10 15.14.35.dat".
- [9] DIGSILENT, "Email with Subject: Protection settings 66 kV Isla - 66 kV Dokweg," 14.01.2021 12:45.

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

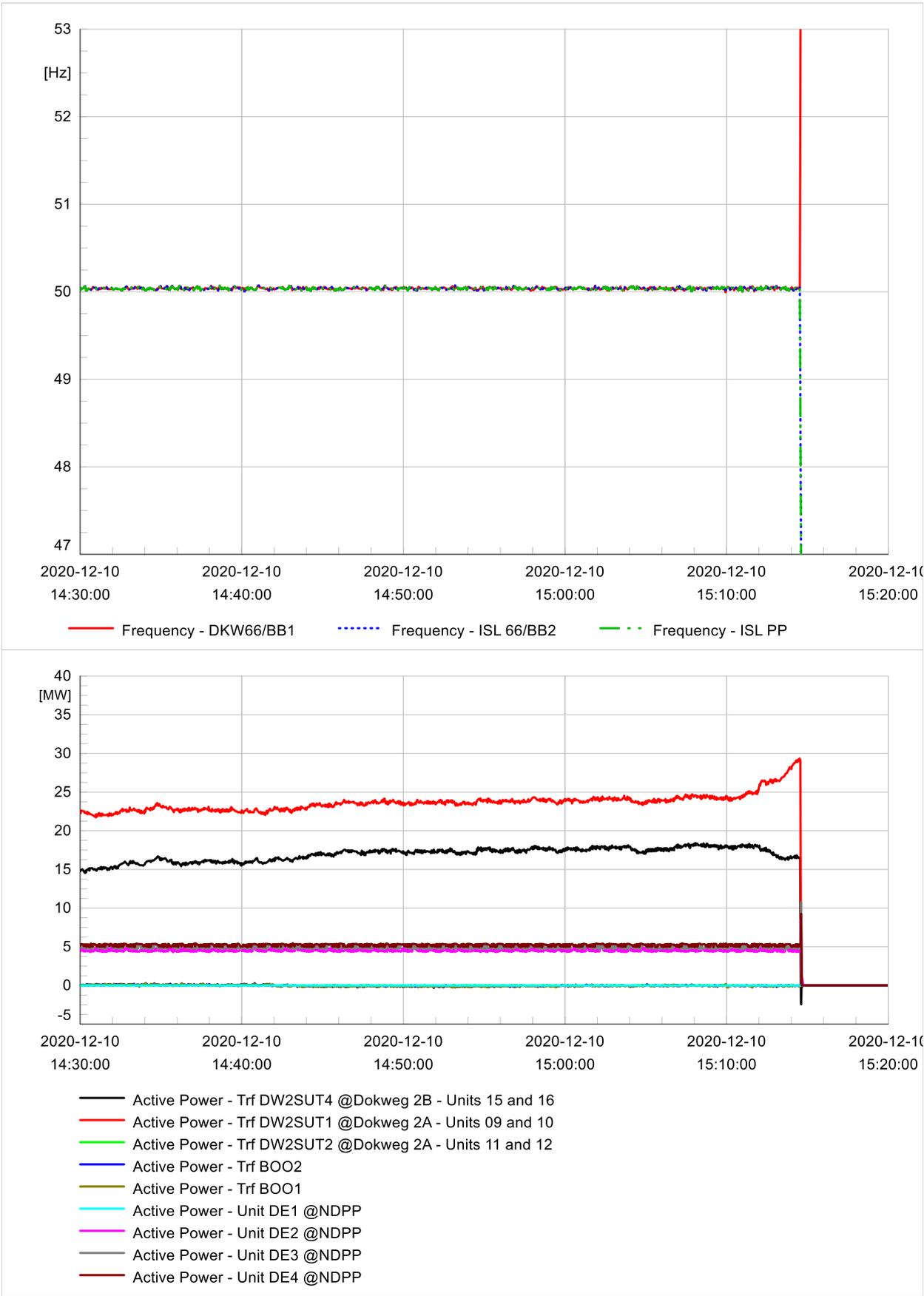


Figure 1: PFM Recordings - Frequency and Active Power – From 14:30:00 to 15:20:00 hours

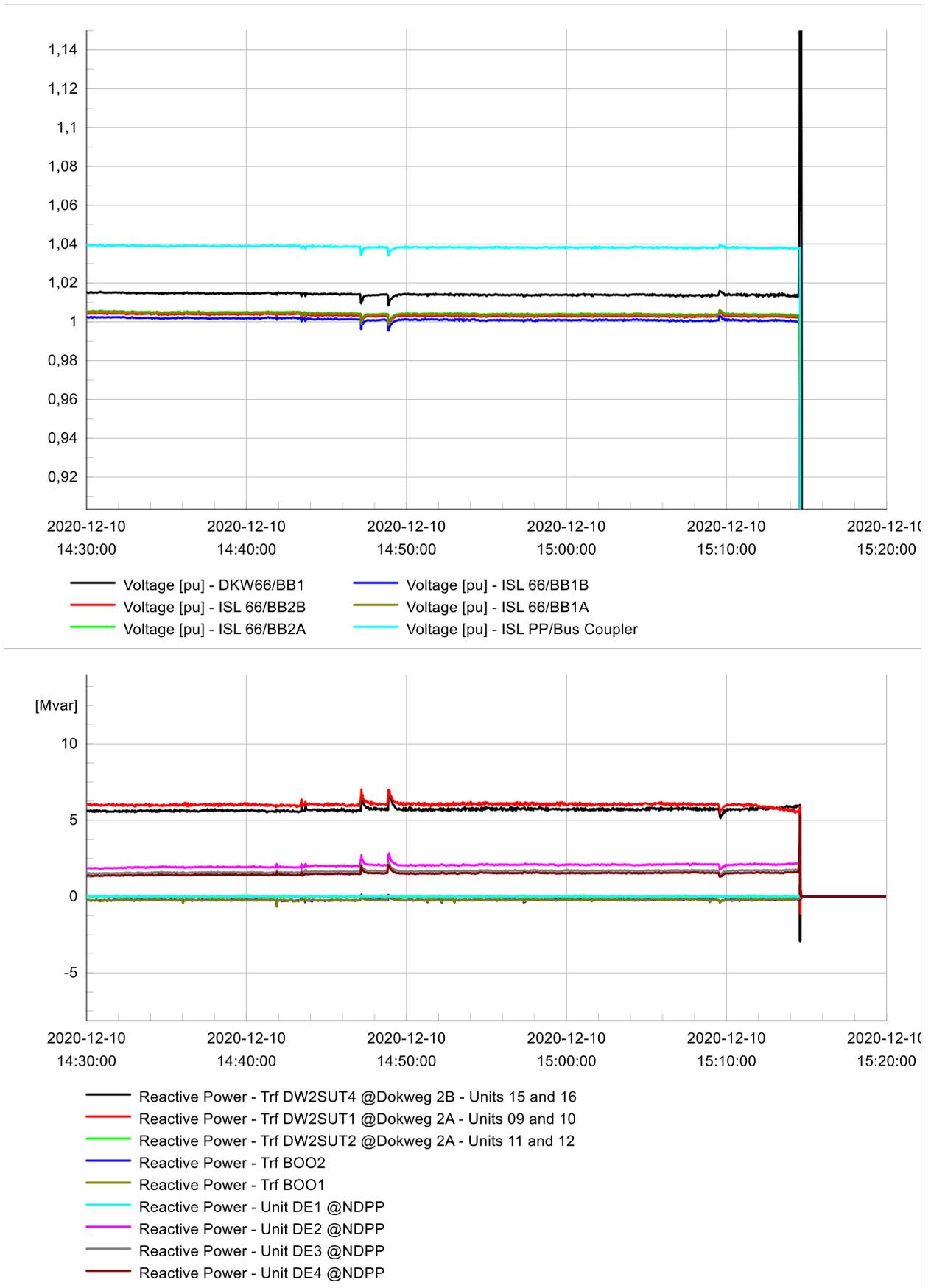


Figure 2: PFM Recordings - Voltage and Reactive Power – From 14:30:00 to 15:20:00 hours

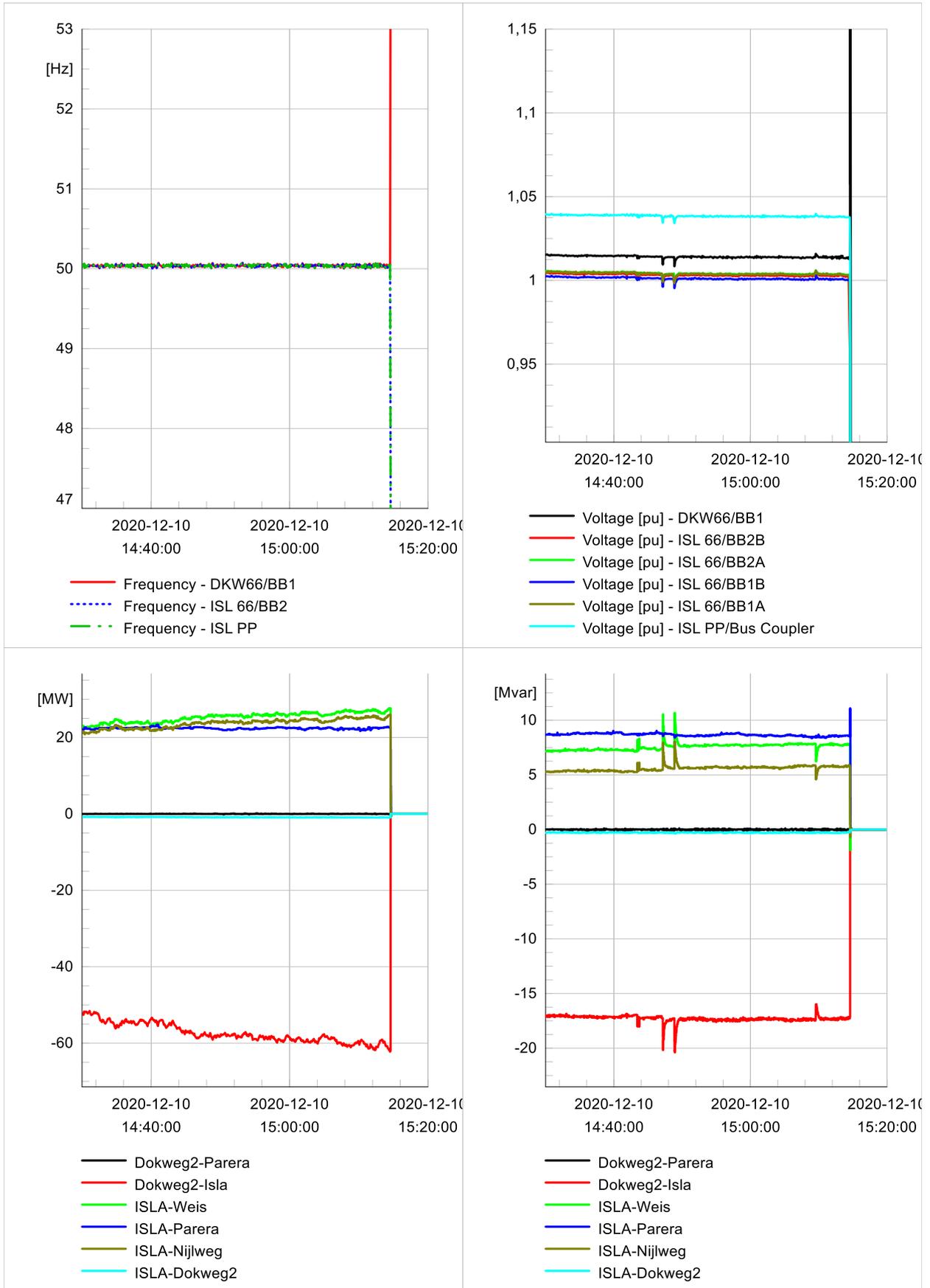


Figure 3: PFM Recordings – Frequency, Voltage and Power across Lines– From 14:30:00 to 15:20:00 hours

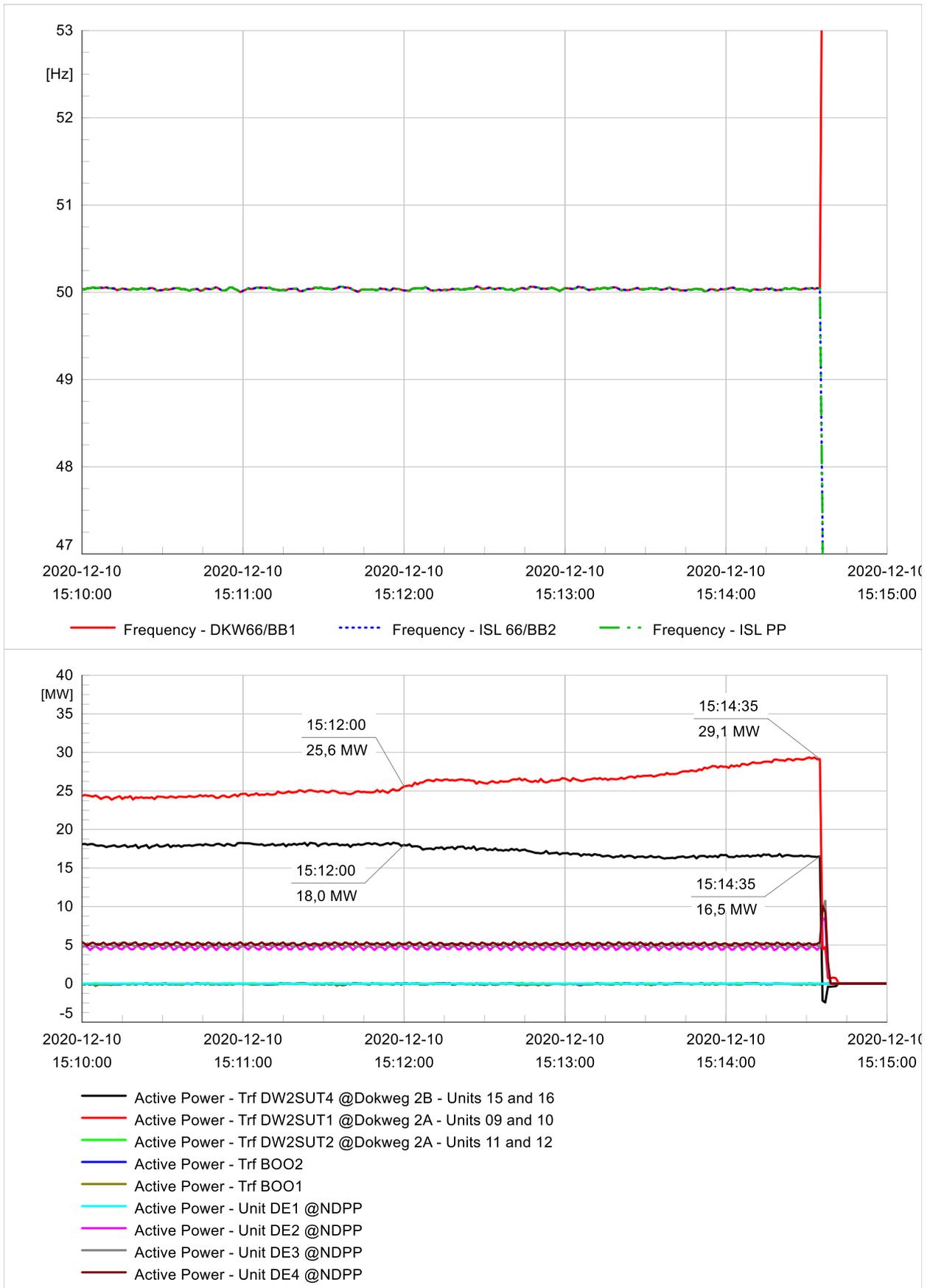


Figure 4: PFM Recordings - Frequency and Active Power – From 15:10:00 to 15:15:00 hours

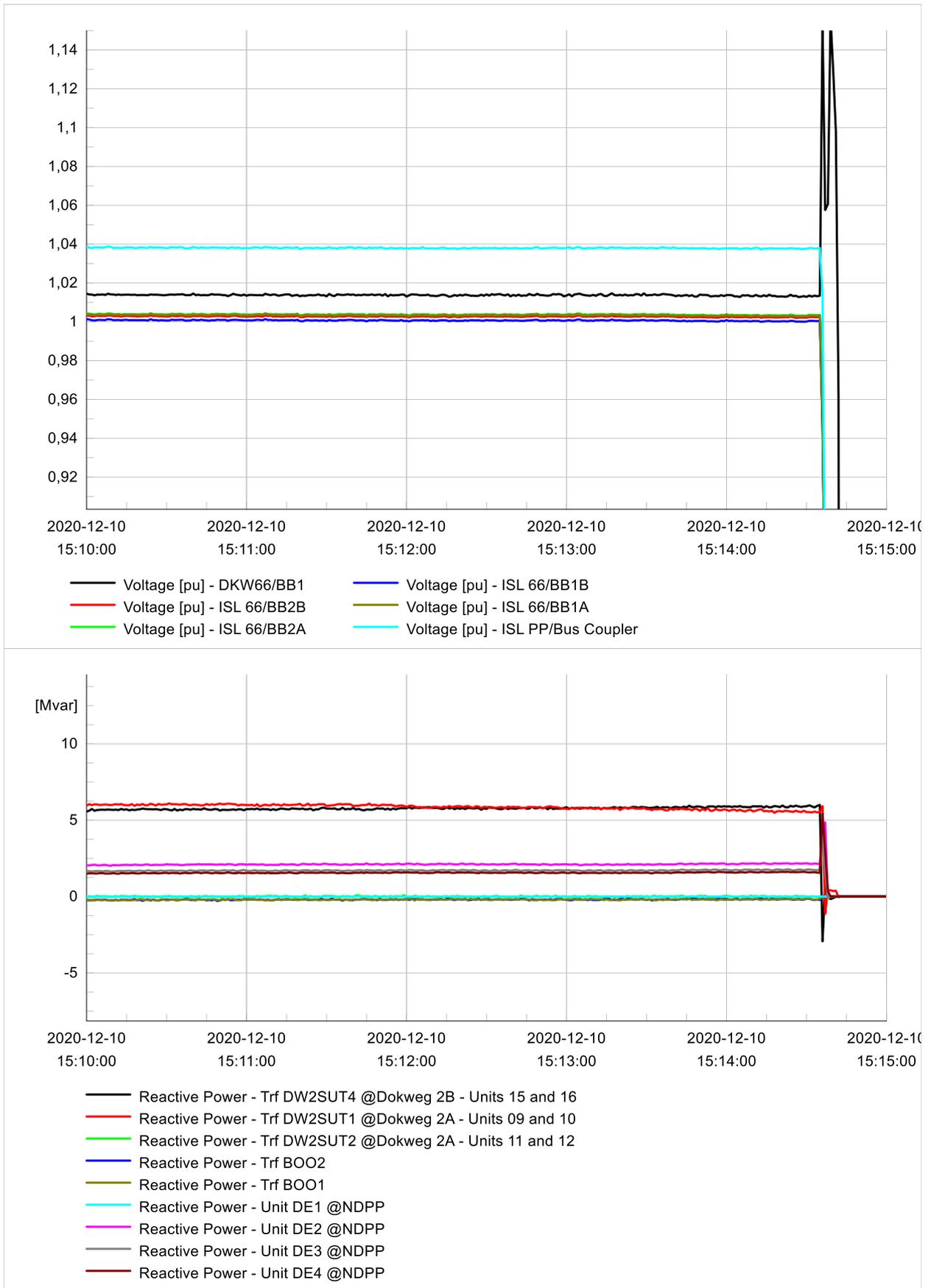


Figure 5: PFM Recordings - Voltage and Reactive Power – From 15:10:00 to 15:15:00 hours

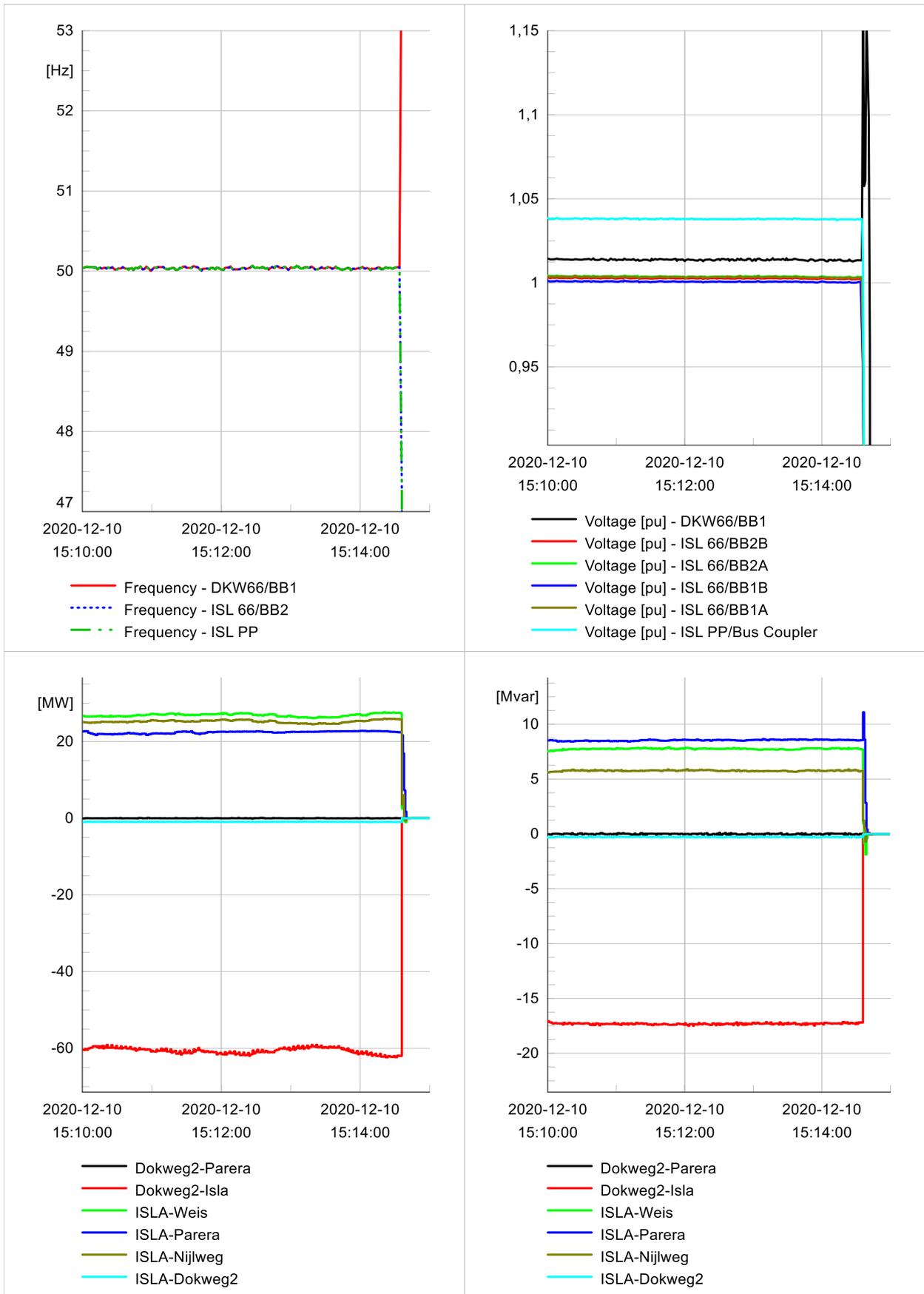


Figure 6: PFM Recordings – Frequency, Voltage and Power across Lines– From 15:10:00 to 15:15:00 hours

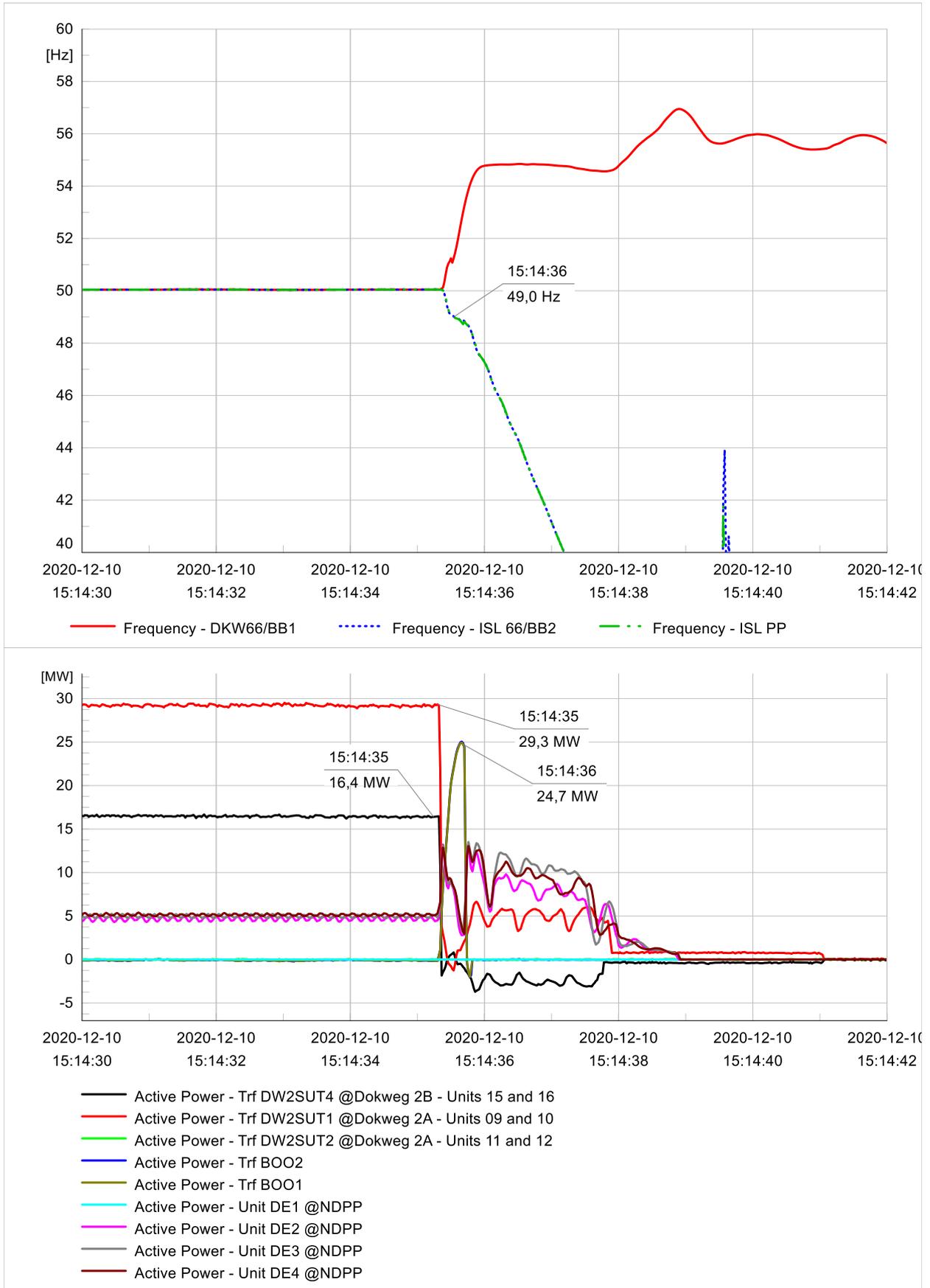


Figure 7: PFM Recordings - Frequency and Active Power – From 15:14:30 to 15:14:42 hours

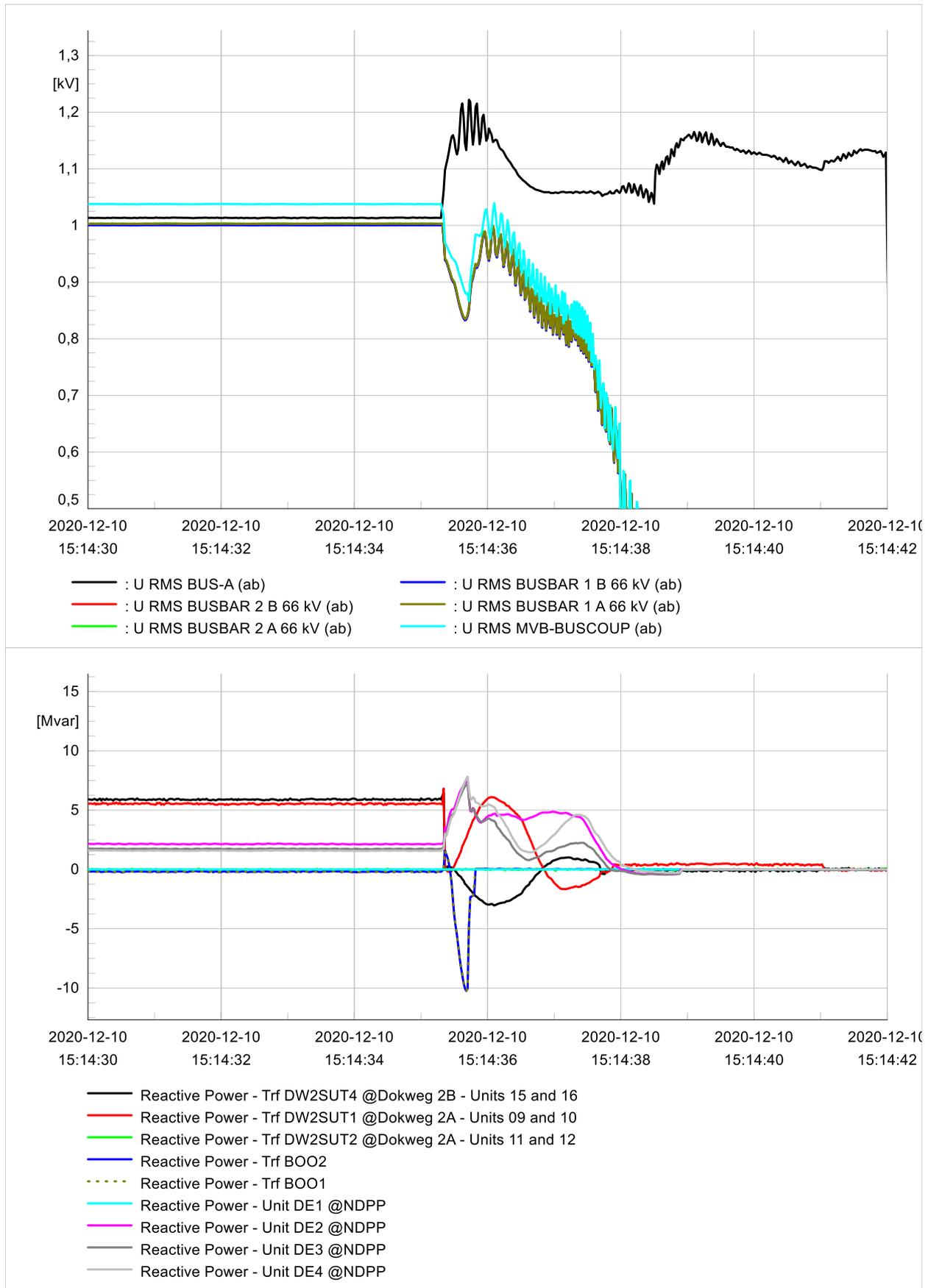


Figure 8: PFM Recordings - Voltage and Reactive Power – From 15:14:30 to 15:14:42 hours

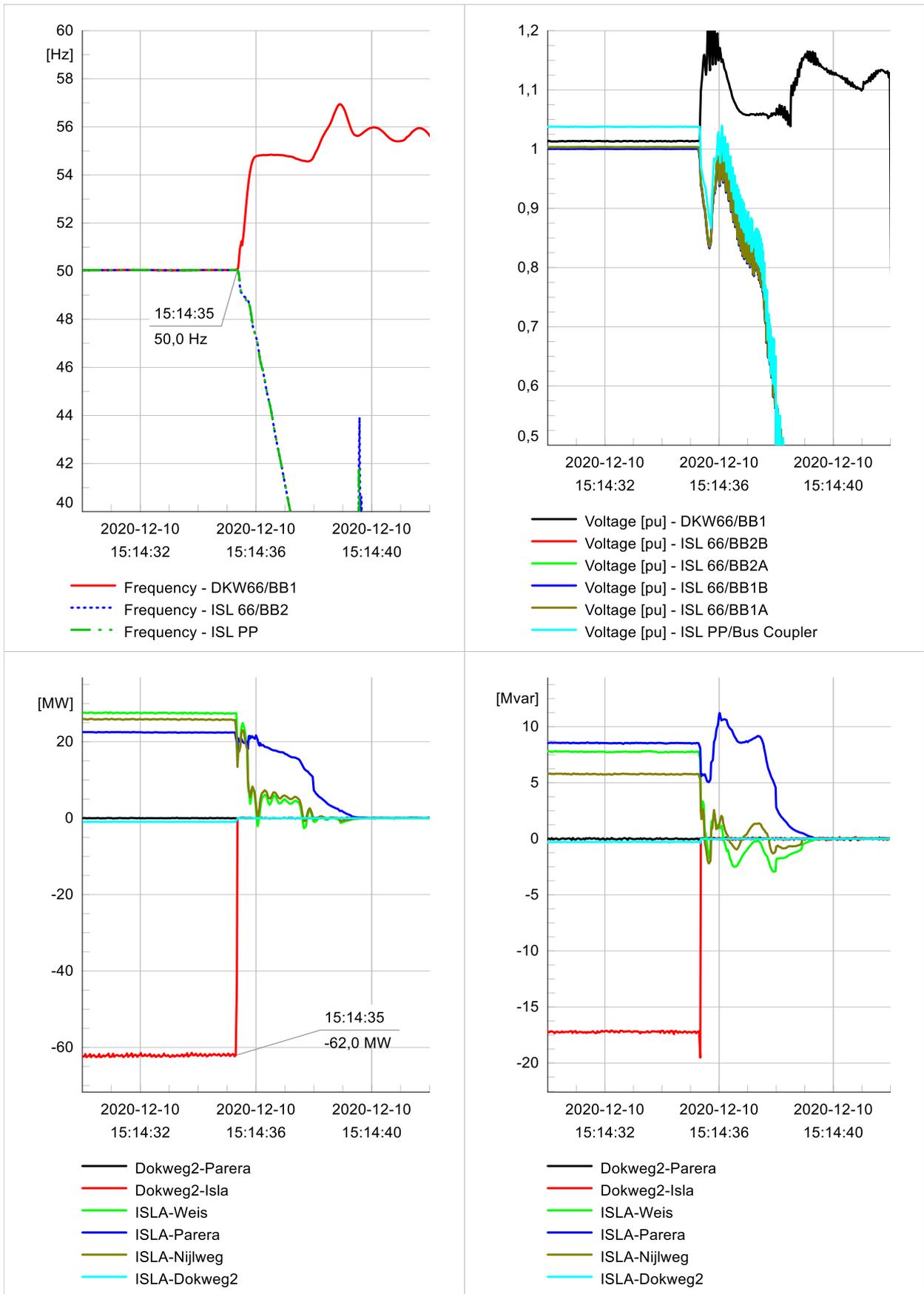


Figure 9: PFM Recordings – Frequency, Voltage and Power across Lines– From 15:14:30 to 15:14:42 hours

9 Annex C: SCADA Recordings

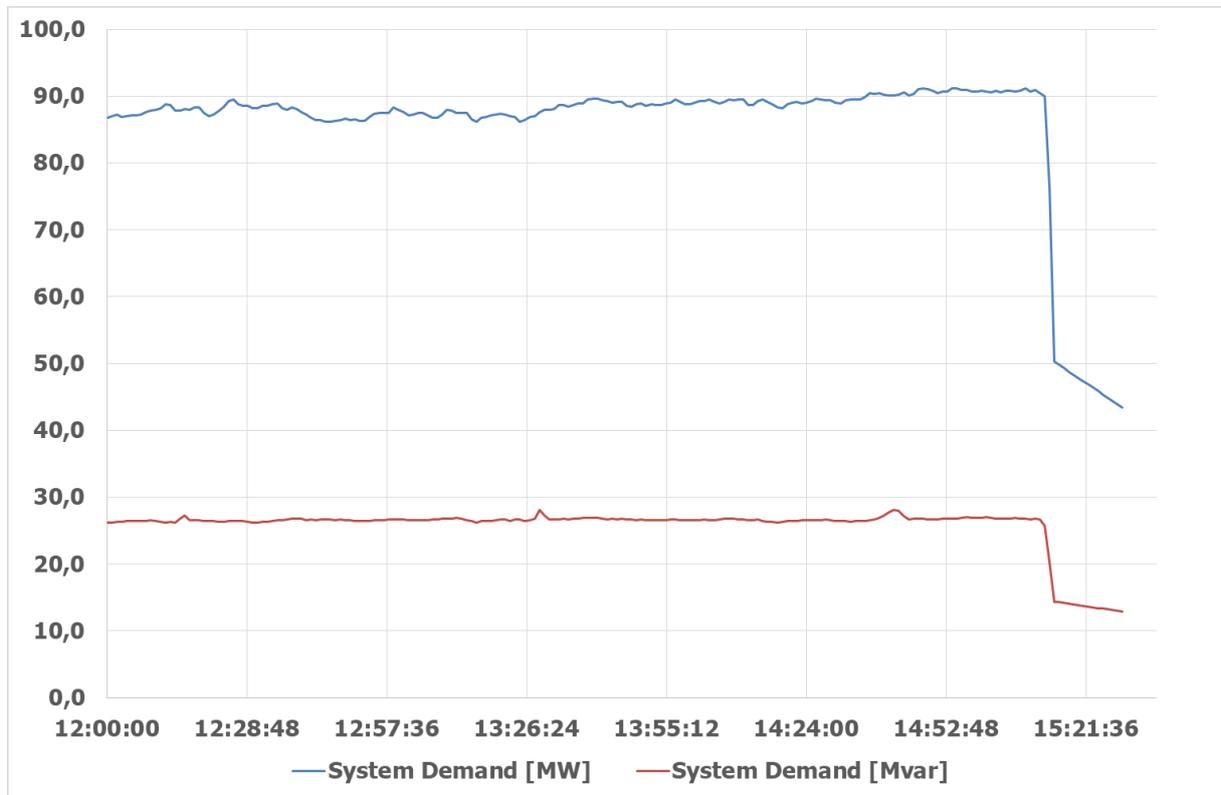


Figure 10: SCADA Recordings – System Demand– From 12:00:00 to 15:22:00 hours

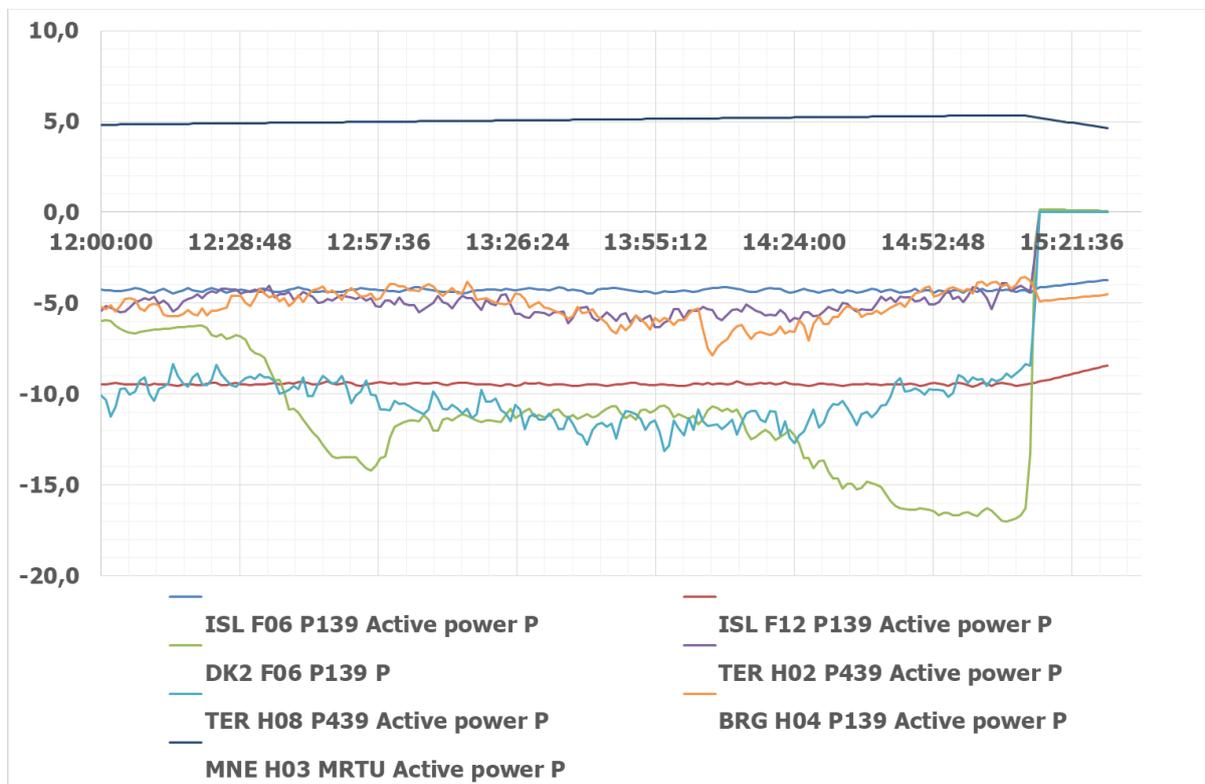


Figure 11: SCADA Recordings – Generation Output Power [MW]– From 12:00:00 to 15:22:00 hours

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

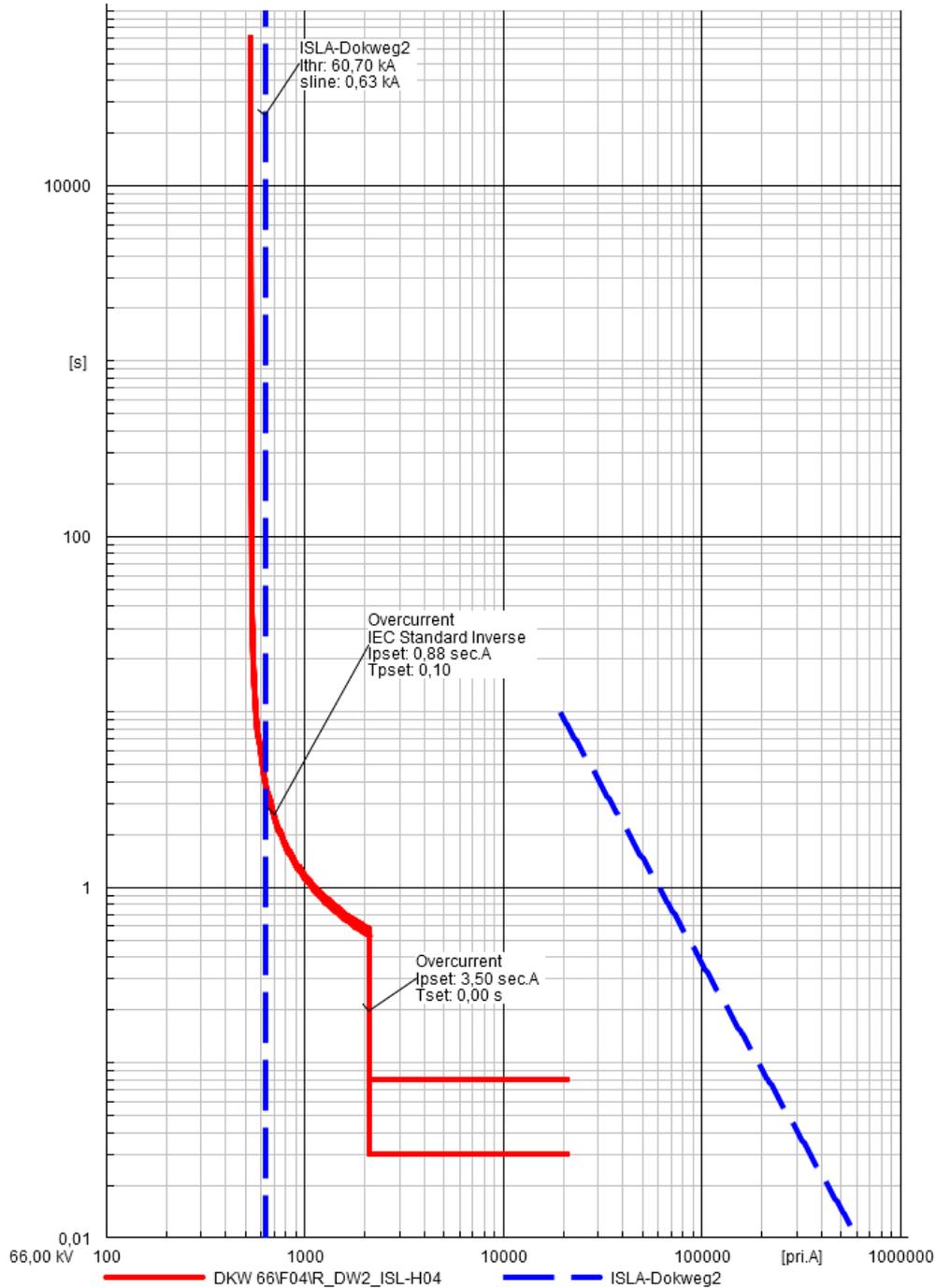


Figure 12: Overcurrent Protection (P139) Settings in Line Dokweg 66kV-Isla 66 kV [9]