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BHP NEWMAN TOWNSHIP ELECTRICITY SUPPLY ANNUAL COMPLIANCE REPORT 2018/2019

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EXECUTIVE SUMMARY

BHP own and operate numerous iron ore mines located at the Pilbara region of WA. The township of Newman is located approximately 1,200 km to the north of Perth and the town's electricity network is owned, governed and operated by BHP Supply Authority (BHPSA).

In accordance with Western Australia Electricity Industry Code 2005 (the Code), the electrical supply authority must publish a report setting out the information described in Schedule 1 of the Code, in respect to each year ending on the 30th of June. This document, known as the A*nnual Compliance Report*, is to provide the full suite of information outlined in Schedule 1 of the Code, relating to the Network Quality and Reliability of Supply.

The methodology adopted to examine compliance/non-compliance with the Code utilizes two notable sources of information as follows:

- Power quality data measured from the Newman 0.415 kV network over a period of seven calendar days or more; and
- Outage data and other relevant information provided by the network operator (BHPSA).

The Code is written in four parts plus a reporting-requirements schedule:

- *Part 1*: Preliminary information associated with term of reference.
- *Part 2*: Quality and reliability standards (further partitioned into 4 *divisions*).
- *Part 3*: Payment to customers for lack of regulatory adherence.
- *Part 4*: Incidental duties as a Supply Authority.
- *Schedule 1*: Information to be published in this report.

This Annual Compliance Report presents the relevant parts of the Code listed above, in particular:

- Power quality criteria pertaining to Newman's distribution network (measured across eight feeders supplying the town, of which four are connected to Town Substation and the remaining four are fed from South Town Substation); and
- The reportable requirements as outlined in Part 2 and Schedule 1 of the Code, for the 2018/19 Financial Year (FY).

With regards to the site measurements, the *average* values of electrical parameters were logged over a period of seven days, at 10-minutes intervals. PQ indices were then calculated and found, in large, well within the limits stipulated by the Code. That is, the *averages* of the following parameters are proven to meet the Code's requirements:

- *Voltage Flicker (short- and long-term criteria);*
- RMS Voltage Magnitude;
- Power System Frequency; and
- *Voltage Total Harmonic Distortion (U-THD)*.

The following compliance issues were however identified:

- *Voltage Flicker*: an increase in the number of short-term and long-term voltage fluctuation breaches (as described in AS61000:2001) is observed compared to the previous years. Total of 17 short-term and 4 long-term breaches were measured. The more onerous breaches were observed on the TC1, TC2, TC3 and TC4 feeders (TC2 in particular). If similar or worsened flicker indices are measured in next year, then further investigations are recommended to identify and mitigate the root-cause.
- *RMS Voltage Magnitude*: a relative increase in the number of voltage level breaches (as described in AS/NZS 3000:2007) was observed compared to the previous years . Given the temporary and random nature of the breaches, they are not deemed of a practical concern at this stage, but this parameter should be monitored more closely over the coming years.
- *Power System Frequency*: A single over-frequency breach of the limits (as described in the Electricity Act of 1945 Section 25(1)(d)) was recorded during the logging period. This event appears to be extremely isolated and hence, was not envisaged to be an issue.
- *U-THD*: A single U-THD breach of the limits (as described in Part 2, Division 1, Section 7 of the Code) was recorded during the logging period. With the exception of the single breach, the average U-THD level recorded on all feeders was consistently below the required limit.
- The recorded individual order harmonics showed a number of temporary and random breaches on all feeders but deemed of no practical concern. The magnitude of these breaches appears to follow a typical daily demand pattern and should the issues persist in coming years, further investigations of the issues are recommended.

Reportable parameters for Newman Township Electricity Supply over the 2018/19 FY (as outlined in the 'Schedule 1' of the Code) are presented below:

- *>12 hour interruptions:* No interruptions were recorded to have exceeded 12 hours.
- No *small use customer* was disconnected from the network more frequent than the Code's requirements (i.e., limit of 16 times).
- No complaints were received from customers during FY 2018/2019.
- The key reliability indices are calculated as listed below:
    - *Customer Average Interruption Duration Index (CAIDI)* of 114 minutes – CAIDI is the average outage duration that any given customer experience (i.e., the average restoration time).
    - *System Average Interruption Frequency Index (SAIFI)* of 2.66 interruptions – SAIFI is the number of interruptions that the customers experienced.
    - *Average Service Availability Index (ASAI)* of 99.93% – ASAI is the perceived availability of the network to the customers.
    - *System Average Interruption Duration Index (SAIDI)* of 376 minutes – SAIDI is the average outage duration for each customer served.

In summary, the metering data collected from the 16 locations throughout the Newman Township network indicate that the power quality is, in large, within the limits stipulated by the Code. It should be noted that although the overall reliability of the Newman Township supply appeared to have degraded when compared to the previous FYs, the overall network performance is still considered to be satisfactory. As such, this report finds the reliability and quality of the supply for Newman Township network in compliance with the Code's requirements.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The township of Newman is located approximately 1,200 km to the north of Perth; the town's electricity network is owned, governed and operated by BHP Billiton Supply Authority (BHPSA). The network encompasses the township of Newman, Newman Airport, Capricorn Roadhouse, town water supply bore field, Mt Whaleback iron ore mine, and several smaller satellite mines in the adjacent areas.

At present, the township of Newman includes 2,501 registered premises comprised of a mixture of residential and commercial customers (compared to 2,385 customers for 2017/18 FY).

According to Western Australia Electricity Industry (Network Quality and Reliability of Supply) Code 2005 (the Code), an electricity distributor must prepare a report setting out the information described in Schedule 1 of the Code, in respect to each year ending on the 30th June.

This Annual Compliance Report presents all information required by "Schedule 1 – Information to be published", relating to supply of electricity, for the period of 1st July 2018 to 30th of June 2019. Measurement information is based on sampled data and outlined in Section 6, whereas outage information is based on data provided by BHPSA and outlined in Section 7.

The compliance statistical analysis has focused solely on Newman Township and the key infrastructure adjacent to the township. The electrical network supplying the BHP mining operation and the surrounding mine leases have not been assessed in this report.

2. ASSUMPTIONS

The terminologies used throughout this compliance report are as defined in the Western Australia Electricity Industry (Network Quality and Reliability of Supply) Code 2005 (the Code).

The logging information gathered over the limited period is indicative of the performance of the network over the complete financial year (2018/2019 FY).

3. METHODOLOGY

The electricity supply compliance review entailed the following processes:

1. The temporary installation of PQ loggers at the beginning and end of the 11 kV feeders emanating from the Town and Southtown Substations (a total of 16 loggers, 2 for each feeder were installed). Each PQ logger was installed on the low voltage (LV) side of pad-mounted transformers. The measuring period lasted between 8 and 10 days between February to April 2019. The PQ measurements were undertaken in accordance with AS 61000.4.30:2007, Annex A (Power Quality Measurements).
2. Interpretation and analysis of the logged PQ data using HIOKI 3196 & 3198 PQ Analysers.
3. The receipt of the following information from BHPSA:
    - Network outage information for planned and forced outages for the Newman Township during the 2018/2019 FY as well as information on customer complaints.
    - Expenditure information as a consequence of network complaints or programs directed to improve reliability or power quality of the network.
4. Identification of any breaches of the Code's provisions and Electricity Act 1945.
5. Statistical analyses and review of network performance.
6. Preparation of a compliance report that fulfils the requirements outlined in the Code.

4. NEWMAN TOWNSHIP PQ MONITORING

4.1. PQ DEVICE SPECIFICATION

The equipment used to undertake the PQ logging were a mixture of the HIOKI 3196 and HIOKI 3198 PQ Analysers. The HIOKI 3198 is the updated iteration of HIOKI 3196 but both types of loggers are practically identical in terms of their features, functionality, and user interface. The HIOKI device can measure multiple waveforms and transient events simultaneously using 4 voltage channels and 4 current channels per device. The device is compliant with AS61000-4-30 Ed 2 Class A, which specifies compatibility with industry standard PQ parameters (further information pertaining to the HIOKI 3196 and HIOKI 3198 is provided in Appendix A). The measurements obtained for the loggers are then extracted and analysed with the accompanying analysis software (HIOKI 9624 V2.50).

4.2. PQ DEVICE LOCATIONS AND IN-SERVICE PERIODS

A total of 4 PQ loggers were deployed across 16 locations on the Newman TC1, TC2, TC3, TC4, STS1, STS2, STS4 and STS6 feeders. The installation locations and times are as listed in Table 1. Figure 1 presents a colour-coded single line diagram of the eight Newman township feeders. Shaded circles indicate the locations at which the PQ loggers were temporary located. All loggers were installed on the LV (secondary) side of pad-mount transformers, due to the difficulty and safety issues surrounding the installation the loggers on the LV side of pole-top transformer.

Table 1 | PQ Logger Locations

ZONE SUB	FEEDER NAME	START/END OF FEEDER	SUBSTATION NAME	DATE INSTALLED	DATE REMOVED
Township	TC1	Start	PS28	11/02/2019 15:06	19/02/2019 13:06
		End	PS68	11/02/2019 14:03	19/02/2019 08:33
	TC2	Start	PS10	15/03/2019 16:40	23/03/2019 13:30
		End	PS14	12/02/2019 11:20	20/02/2019 13:20
	TC3	Start	PS108	08/03/2019 10:40	14/03/2019 16:40
		End	PS69	20/02/2019 10:50	27/02/2019 07:30
	TC4	Start	PS125	15/03/2019 17:34	23/03/2019 14:04
		End	PS15	20/02/2019 11:57	28/02/2019 14:07
South Town	STS1	Start	PS94	20/02/2019 15:40	26/02/2019 23:00
		End	PS25	07/03/2019 16:46	15/03/2019 16:26
	STS2	Start	PS60	28/03/2019 08:29	04/04/2019 12:59
		End	PS70	27/02/2019 14:40	07/03/2019 16:20
	STS4	Start	PS111	08/03/2019 13:50	16/03/2019 08:30
		End	PS44	08/03/2019 14:27	16/03/2019 13:37
	STS6	Start	PS129	28/02/2019 15:51	08/03/2019 07:21
		End	PS122	28/02/2019 16:40	08/03/2019 07:50

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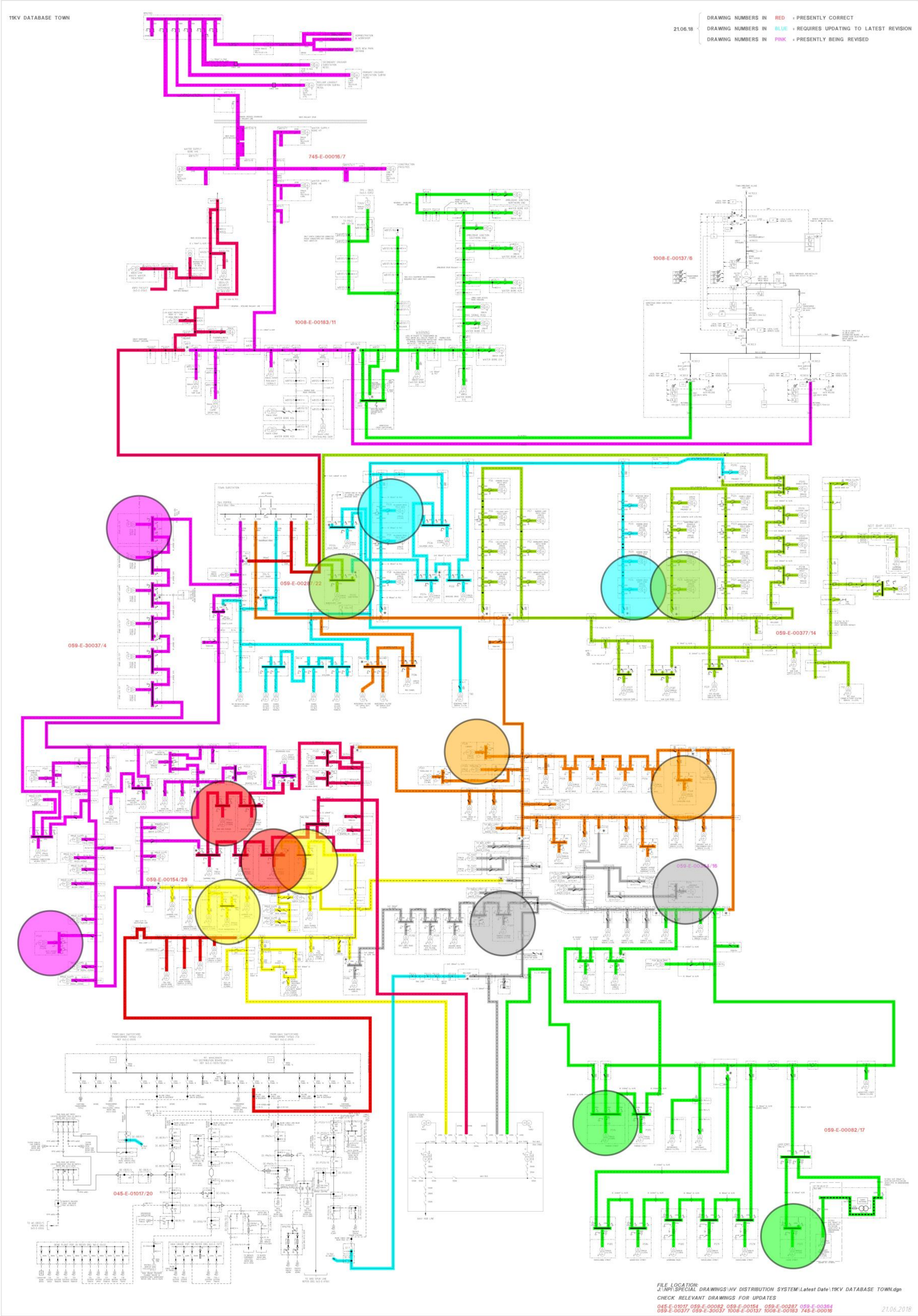

Figure 1 | Single Line Diagram of the Newman township (shaded circles indicate the location of PQ loggers)

4.3. PQ DEVICE SETUP

The setup of the PQ loggers was as per the relative HIOKI instruction manual. As shown in the frequency and voltage time-based PQ plots in Appendix B, three values have been logged and plotted: the maximum RMS, the average RMS and the minimum RMS value over the recording interval. The recording interval setup in the PQ loggers was five minutes, with the exception of flicker which uses 10-minute intervals. That is, over the course of the in-service days the PQ loggers sampled various time-based parameters (e.g., Hz, U and I) at five minutes per sample; and at the end of every sampling interval the three RMS values where recorded.

Figure 2 is an extract from the HOIKI instruction manual depicting the sampling and interval-recording of maximum, average and minimum RMS values.

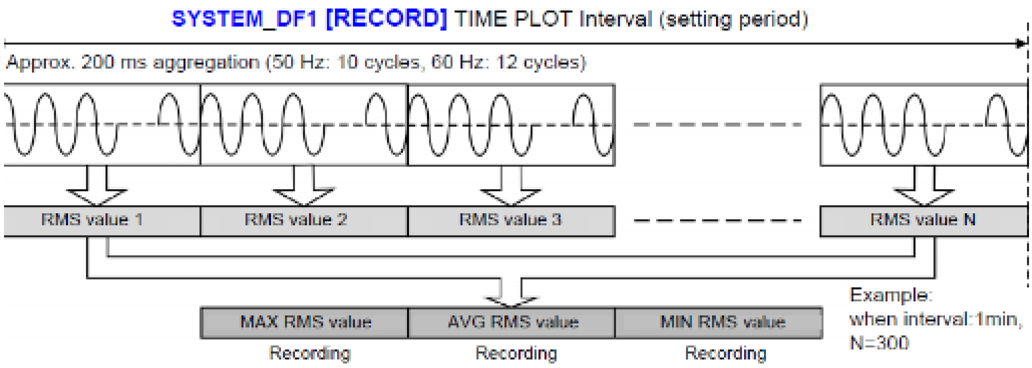

Figure 2 | Sampling and interval recording philosophy used in the Hioki PQ loggers (from Hioki Manual)

5. COMPLIANCE REQUIREMENTS

This section summaries the *Compatibility Levels* by which a 'Distributors' electrical network is to comply with, as outline by the Code.

5.1. VOLTAGE FLUCTUATIONS

5.1.1. FLICKER

The Code specifies that flicker shall comply with long- and short-term flicker 'compatibility levels' as per AS 61000:2001. The compatibility levels are shown below in Table 2, and are a measure of the voltage quality limits over a 10 minute and two-hour interval for short (P_{ST}) and long term (P_{LT}) flicker, respectively.

Table 2 | Short- and long-term flicker limits

COMPATIBILITY LEVEL	VALUE
Short Term (P_{ST})	1.0
Long Term (P_{LT})	0.8

5.1.2. VOLTAGE LEVELS

In accordance with AS 3000:2018 the voltage levels of the electrical network must be maintained between +10%/-6% of the nominal 240 V single-phase supply voltage.

5.2. FREQUENCY

The Code specifies that the frequency fluctuation shall adhere to the Electricity Act 1945 with the level to be maintained at ±2.5% of 50 Hz.

5.3. VOLTAGE TOTAL HARMONIC DISTORTION

Part 2, Division 1, Section 7 of the Code specifies that the voltage total harmonic distortion (U-THD) may not exceed 8%. Individual odd and even harmonic components are not to exceed the values shown below in Table 3.

Table 3 | Harmonic compatibility levels (in percentage of nominal voltage)

EVEN HARMONICS		ODD HARMONICS (MULTIPLES OF 3)		ODD HARMONICS (NON-MULTIPLES OF 3)	
ORDER (H)	HARMONIC VOLTAGE (%)	ORDER (H)	HARMONIC VOLTAGE (%)	ORDER (H)	HARMONIC VOLTAGE (%)
2	2	3	5	5	6
4	1	9	1.5	7	5
6	0.5	15	0.3	11	3.5
8	0.5	21	0.2	13	3
10	0.5	>21	0.2	17	2
12	0.2			19	1.5
>12	0.2			23	1.5
				25	1.5
				>25	0.2 + 1.3(25/h)

5.4. POWER INDUSTRY RELIABILITY INDICATORS

As per Schedule 1, Clause 11 (a) to (d) of the Code, a number of reliability indicators (e.g. interruption durations and quantity of interruptions) are required to be reported. To achieve the Code's requirement, the following standard utility reliability indices have been used.

5.4.1. CUSTOMER AVERAGE INTERRUPTION DURATION INDEX (CAIDI)

Customer Average Interruption Duration Index is defined as the sum of the duration of each customer interruption (in minutes) divided by the number of distribution customers served.

$$CAIDI_{Minutes} = \frac{\sum Customer\ Interruption\ Durations}{\sum Customer\ Interruptions} = \frac{SAIDI}{SAIFI}$$

5.4.2. SYSTEM AVERAGE INTERRUPTION FREQUENCY INDEX (SAIFI)

System Average Interruption Frequency Index is defined as the sum of the frequency of each sustained distribution customer interruption (in interruption events) attributable to the distribution system divided by the number of distribution customers served.

$$SAIFI_{Minutes} = \frac{\sum Number\ of\ Sustained\ Distribution\ Customer\ Interruptions}{\sum Number\ of\ Distribution\ Customers\ Served}$$

5.4.3. AVERAGE SERVICE AVAILABILITY INDEX (ASAI)

Average Service Availability Index is the percentage of time that the service is available to the network customers in a reportable year.

$$ASAI_{Percent} = 1 - \frac{SAIDI_{Hours}}{8760}$$

5.4.4. SYSTEM AVERAGE INTERRUPTION DURATION INDEX (SAIDI)

System Average Interruption Duration Index is defined as the sum of the duration of each sustained distribution customer interruption (in minutes) attributable to the distribution system divided by the number of distribution customers served.

$$SAIDI_{Minutes} = \frac{\sum Sustained\ Distribution\ Customer\ Interruption\ Durations}{\sum Number\ of\ Distribution\ Customers\ Served}$$

6. SITE MEASUREMENTS (PQ LOGGER DATA)

The following sections describe the results and notable PQ events which have been recorded by the loggers for each of the eight feeders.

6.1. FEEDER TC1

The PQ logger at the start of the TC1 feeder was installed at the PS28 Library substation between 11/02/2019 and 19/02/2019, satisfying the seven-day minimum logging duration requirement. The PQ logger at the end of the TC1 feeder was installed at the PS68 Capricorn Oval substation between 11/02/2019 and 19/02/2019, satisfying the seven-day minimum logging duration requirement. As shown in Figure 1 (Orange), TC1 originates from the Town substation. The TC1 feeder is a feeder that supplies a number of older distribution substations.

6.1.1. FLICKER

The logged flicker data for the start and end of the TC1 feeder is shown from Figure 23 to Figure 28 in Appendix B.1. Table 4 below lists the recorded breach events during the logging period.

Table 4 | Feeder TC1 Flicker Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	FLICKER EVENT DETAILS/MAGNITUDE
TC1 Start (PS28)	R/W/B	13/02/2019 15:56:29	P_{ST} limit (1.0) exceeded: R=1.662, W=1.743, B=1.058
		19/02/2019 10:36:29	P_{ST} limit (1.0) exceeded: R=1.932, W=1.350, B=1.139
TC1 Start (PS28)	R/W	19/02/2019 11:16:29	P_{ST} limit (1.0) exceeded: R=1.144, W=1.404
TC1 Start (PS28)	R	19/02/2019 10:36:29 until 12:26:29	P_{LT} limit (0.8) exceeded for a duration of approximately two hours: R_{MAX}=0.91
TC1 End (PS68)	R/W/B	13/02/2019 15:53:26	P_{ST} limit (1.0) exceeded: R=1.06, W=1.648, B=1.789

6.1.2. VOLTAGE

The logged voltage level data for the start and end of the TC1 feeder is shown from Figure 29 to Figure 34 in Appendix B.1. Table 5 below lists the recorded breach events during the logging period.

Table 5 | Feeder TC1 Voltage Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	VOLTAGE EVENT DETAILS/MAGNITUDE
TC1 Start (PS28)	R/W/B	13/02/2019 15:56:29	Undervoltage limit (-6%) exceeded: R=207.63 V, W=207.83 V, B=217.27 V
TC1 End (PS68)	R/W/B	13/02/2019 15:53:26	Undervoltage limit (-6%) exceeded: R=220.13 V, W=210.11 V, B=210.11 V

6.1.3. FREQUENCY

The logged frequency data for the start and end of the TC1 feeder is shown in Figure 35 and Figure 36 in Appendix B.1. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.1.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the TC1 feeder is shown from Figure 37 to Figure 42 in Appendix B.1. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.1.5. HARMONICS

The logged harmonic data for the start and end of the TC1 feeder is shown from Figure 43 to Figure 50 in Appendix B.1. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 5 and Figure 6.

A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 3 and Figure 4. The power quality measurements recorded on the TC1 feeder and given in the "*W_APD05688 2017-2018 Annual Compliance Report*" indicated a large number of non-compliant 24^{th} order harmonics attributed to unbalanced three-phase loads supplied from the Town substation. The power quality measurements recorded on the TC1 feeder for this report show only temporary and random breaches. Given this and the lack of 24^{th} order harmonics, these events are not deemed of any practical concern (i.e. not deemed as compliance issues).

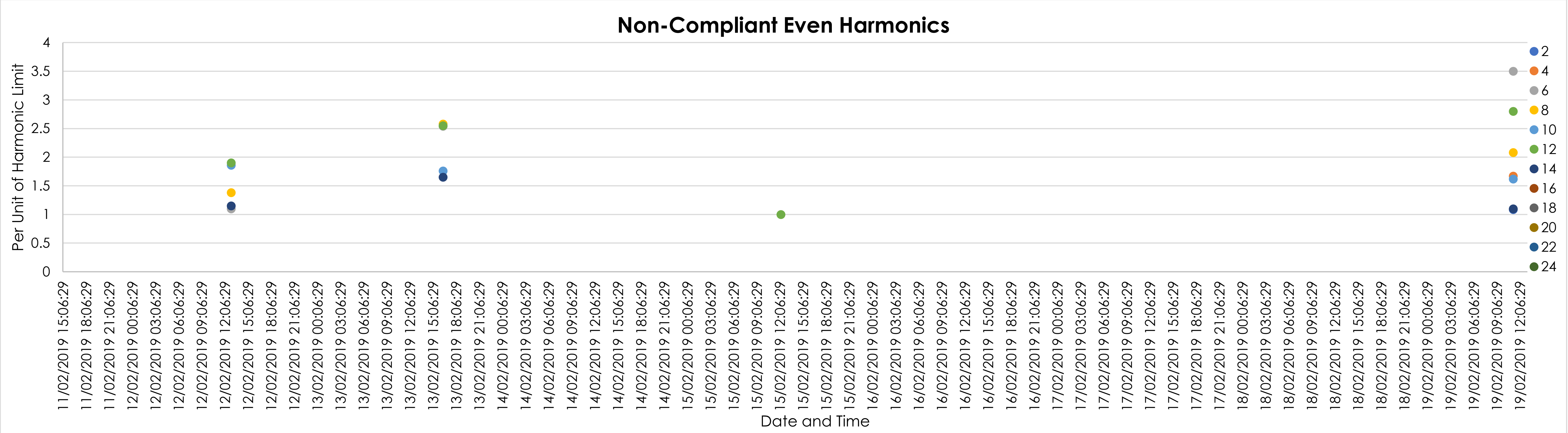

Figure 3 | Feeder TC1 (Start) - Non-Compliant Even Harmonics

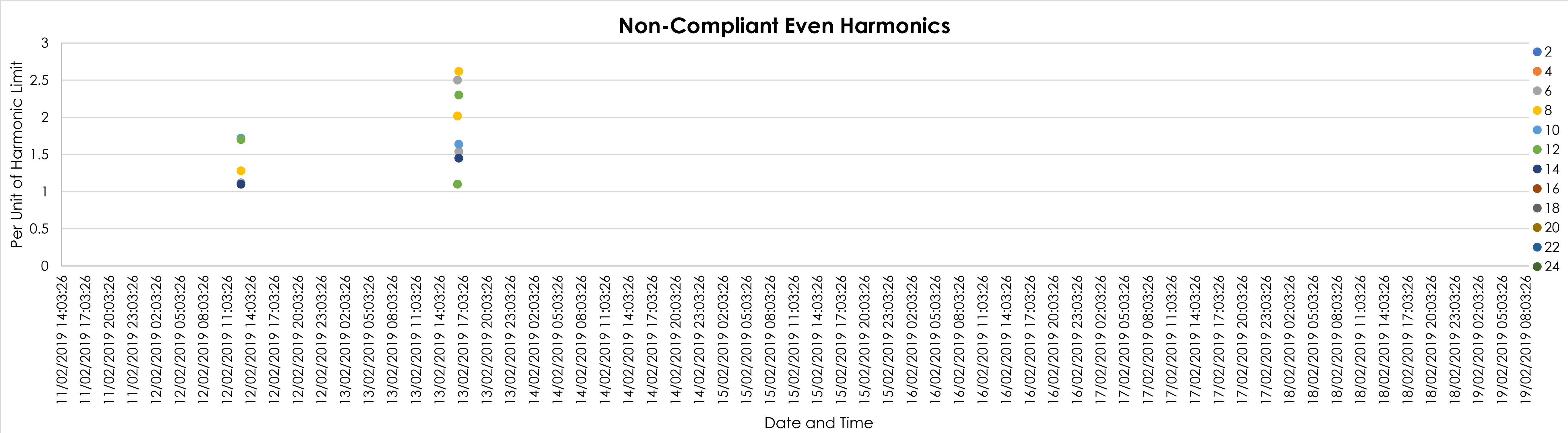

Figure 4 | Feeder TC1 (End) - Non-Compliant Even Harmonics

6.2. FEEDER TC2

The PQ logger at the start of the TC2 feeder was installed at the PS10 McLennan Drive substation between 15/03/2019 and 23/03/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the TC2 feeder was installed at the PS14 Bondini Drive substation between 12/02/2019 and 20/02/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Cyan), TC2 originates from the Town substation.

6.2.1. FLICKER

The logged flicker data for the start and end of the TC2 feeder is shown from Figure 51 to Figure 56 in Appendix B.2. Table 6 below lists the recorded breach events during the logging period.

Table 6 | Feeder TC2 Flicker Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	FLICKER EVENT DETAILS/MAGNITUDE
TC2 Start (PS10)	R	23/03/2019 11:30:00	P_{ST} limit (1.0) exceeded: R=15.861
TC2 Start (PS10)	R	23/03/2019 11:30:00 until 13:20:00	P_{LT} limit (0.8) exceeded for a duration of approximately two hours: R_{MAX}=6.928
TC2 End (PS14)	W/B	13/02/2019 16:00:00	P_{ST} limit (1.0) exceeded: W=1.531, B=1.626
TC2 End (PS14)	R/W/B	14/02/2019 16:10:00	P_{ST} limit (1.0) exceeded: R=2.125, W=2.833, B=2.283
TC2 End (PS14)	R/W/B	19/02/2019 10:40:00	P_{ST} limit (1.0) exceeded: R=1.113, W=1.839, B=1.313
TC2 End (PS14)	W/B	19/02/2019 11:20:00	P_{ST} limit (1.0) exceeded: W=1.102, B=1.399
TC2 End (PS14)	R/W/B	14/02/2019 16:10:00 until 18:00:00	P_{LT} limit (0.8) exceeded for a duration of approximately two hours: R_{MAX}=0.929, W_{MAX}=1.238, B_{MAX}=0.999
TC2 End (PS14)	W	19/02/2019 10:40:00 until 12:30:00	P_{LT} limit (0.8) exceeded for a duration of approximately two hours: R_{MAX}=0.858

6.2.2. VOLTAGE

The logged voltage level data for the start and end of the TC2 feeder is shown from Figure 57 to Figure 62 in Appendix B.2. Table 7 below lists the recorded breach events during the logging period.

Table 7 | Feeder TC2 Voltage Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	VOLTAGE EVENT DETAILS/MAGNITUDE
TC2 Start (PS10)	R	23/03/2019 11:30:00	Undervoltage limit (-6%) exceeded: R=149.02 V
TC2 End (PS14)	R/W/B	13/02/2019 16:00:00	Undervoltage limit (-6%) exceeded: R=219.69 V, W=209.14 V, B=209.33 V
TC2 End (PS14)	R/W/B	14/02/2019 16:10:00	Undervoltage limit (-6%) exceeded: R=212.61 V, W=209.67 V, B=213.97 V

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6.2.3. FREQUENCY

The logged frequency data for the start and end of the TC2 feeder is shown in Figure 63 and Figure 64 in Appendix B.2. Table 8 below lists the recorded breach events during the logging period.

Table 8 | Feeder TC2 Frequency Breach Event Details

LOCATION	DATE AND TIME	FREQUENCY EVENT DETAILS/MAGNITUDE
TC2 Start (PS10)	23/03/2019 11:30:00	Over frequency limit (2.5%) exceeded: f=64.929 Hz

6.2.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the TC2 feeder is shown from Figure 65 to Figure 70 in Appendix B.2. Table 9 below lists the recorded breach events during the logging period.

Table 9 | Feeder TC2 THD Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	THD EVENT DETAILS/MAGNITUDE
TC2 Start (PS10)	R	23/03/2019 11:30:00	THD limit (8%) exceeded: R=29.67%

6.2.5. HARMONICS

The logged harmonic data for the start and end of the TC2 feeder is shown from Figure 71 to Figure 78 in Appendix B.2. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 5 through to Figure 7. Given the temporary and random nature of the breaches, they are not deemed of any practical concern (i.e. not deemed as compliance issues).

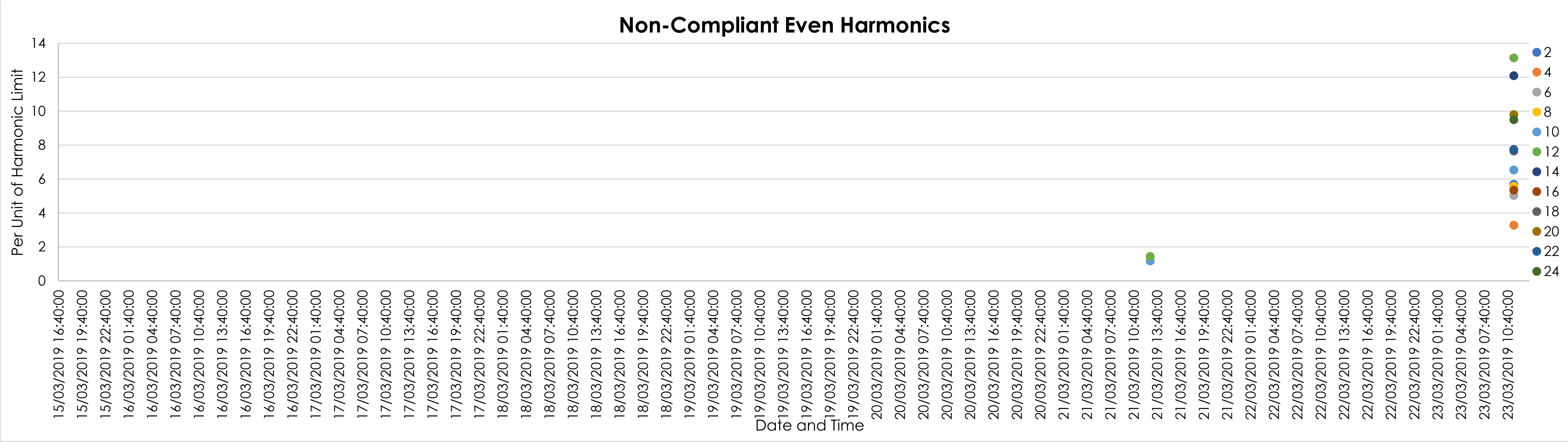


Figure 5 | TC2 Feeder (Start) - Non-Compliant Even Harmonics

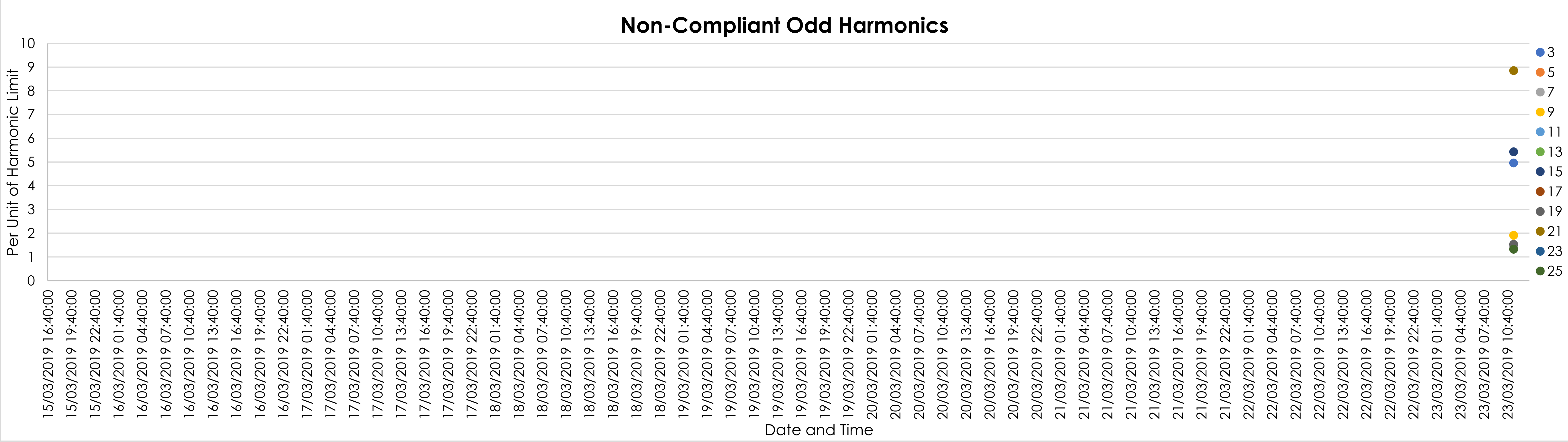


Figure 6 | TC2 Feeder (Start) - Non-Compliant Odd Harmonics

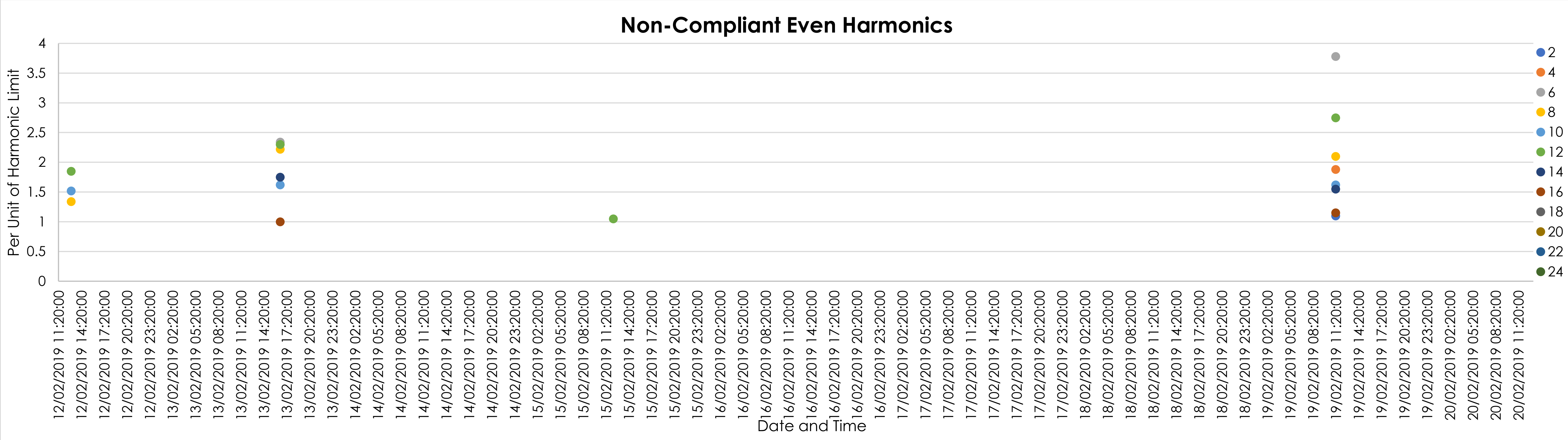


Figure 7 | TC2 Feeder (End) - Non-compliant Even Harmonics

6.3. FEEDER TC3

The PQ logger at the start of the TC3 feeder was installed at the PS108 Les Tutt Drive substation between 08/03/2019 and 14/03/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the TC3 feeder was installed at the PS69 Giles Avenue substation between 20/02/2019 and 27/02/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Purple), TC3 originates from the Town substation.

6.3.1. FLICKER

The logged flicker data for the start and end of the TC3 feeder is shown from Figure 79 to Figure 84 in Appendix B.3. Table 10 below lists the recorded breach events during the logging period.

Table 10 | Feeder TC3 Flicker Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	FLICKER EVENT DETAILS/MAGNITUDE
TC3 End (PS69)	W/B	20/02/2019 15:00:06	P_{ST} limit (1.0) exceeded: W=1.074, B=1.095
TC3 End (PS69)	R/W/B	23/02/2019 04:10:06	P_{ST} limit (1.0) exceeded: R=1.023, W=1.009, B=1.031
TC3 End (PS69)	B	23/02/2019 15:10:06	P_{ST} limit (1.0) exceeded: B=1.05

6.3.2. VOLTAGE

The logged voltage level data for the start and end of the TC3 feeder is shown from Figure 85 to Figure 90 in Appendix B.3. Table 11 below lists the recorded breach events during the logging period.

Table 11 | Feeder TC3 Voltage Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	VOLTAGE EVENT DETAILS/MAGNITUDE
TC3 End (PS69)	W	20/02/2019 15:00:06	Undervoltage limit (-6%) exceeded: W=224.75 V
TC3 End (PS69)	B	23/02/2019 15:05:06	Undervoltage limit (-6%) exceeded: B=222.37 V

6.3.3. FREQUENCY

The logged frequency data for the start and end of the TC3 feeder is shown in Figure 91 and Figure 92 in Appendix B.3. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.3.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the TC3 feeder is shown from Figure 93 to Figure 98 in Appendix B.3. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.3.5. HARMONICS

The logged harmonic data for the start and end of the TC3 feeder is shown from Figure 99 to Figure 106 in Appendix B.3. A summary of non-compliant harmonics and the scale of non-compliances is shown below in Figure 8 through to Figure 10. Given the temporary and random nature of the breaches, they are not deemed of any practical concern (i.e. not deemed as compliance issues).

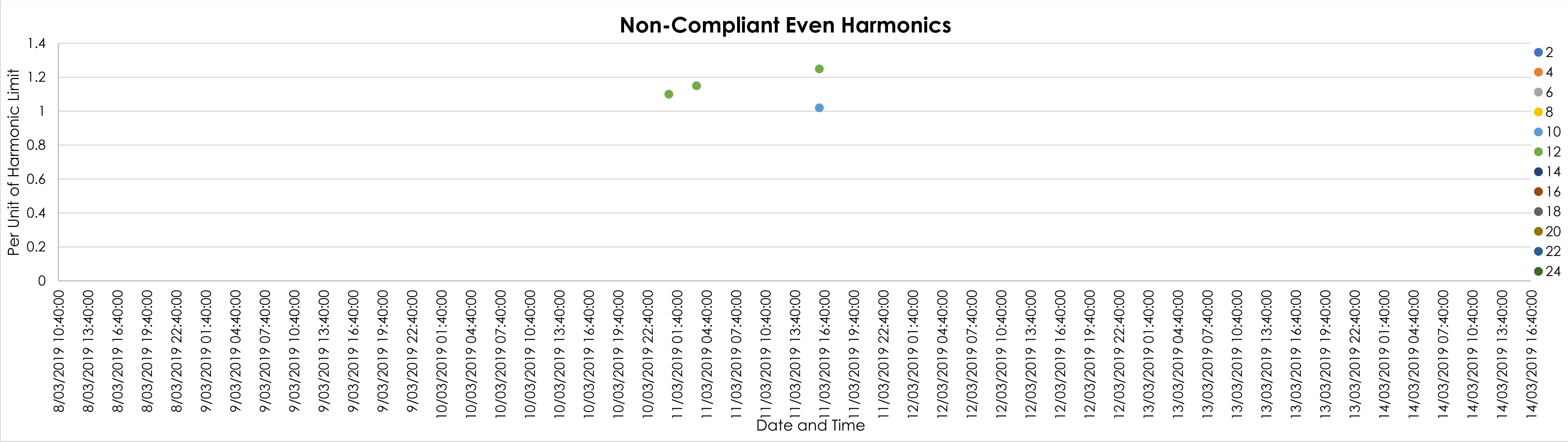


Figure 8 | TC3 Feeder (Start) - Non-Compliant Even Harmonics

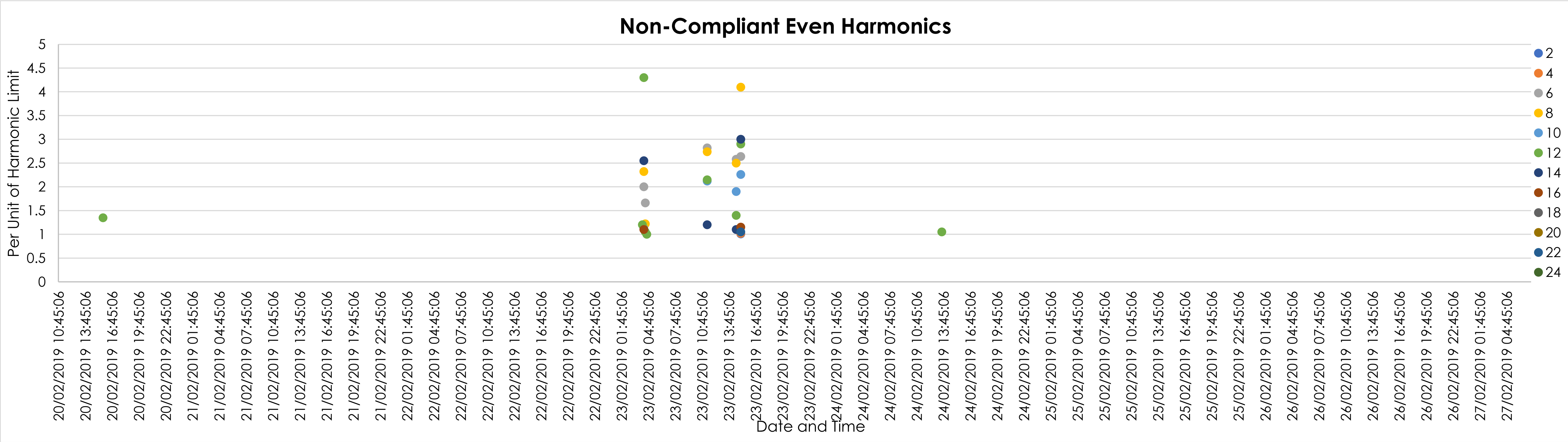


Figure 9 | TC3 Feeder (End) - Non-Compliant Even Harmonics

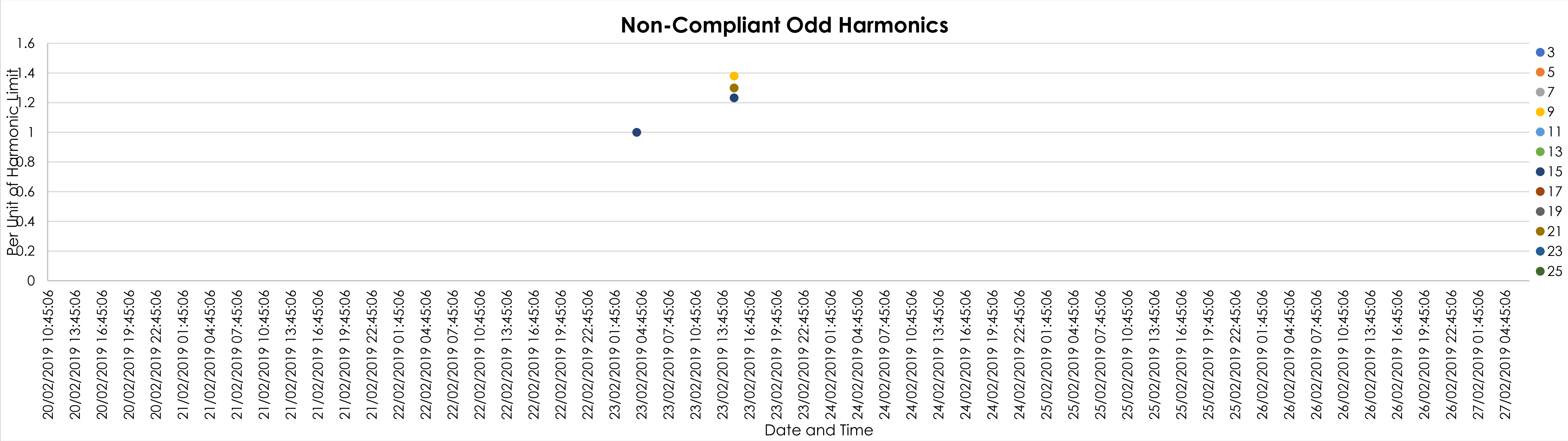


Figure 10 | TC3 Feeder (End) - Non-Compliant Odd Harmonics

6.4. FEEDER TC4

The PQ logger at the start of the TC4 feeder was installed at the PS125 Bubbacurry Loop substation between 15/03/2019 and 23/03/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the TC4 feeder was installed at the PS15 Karrawan Way substation between 20/02/2019 and 27/02/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Green), TC4 originates from the Town substation.

6.4.1. FLICKER

The logged flicker data for the start and end of the TC4 feeder is shown from Figure 107 to Figure 112 in Appendix B.4. Table 12 below lists the recorded breach events during the logging period.

Table 12 | Feeder TC4 Flicker Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	FLICKER EVENT DETAILS/MAGNITUDE
TC4 End (PS15)	W/B	20/02/2019 14:57:33	P_{ST} limit (1.0) exceeded: W=1.09, B=1.106
TC4 End (PS15)	R/W/B	23/02/2019 04:07:33	P_{ST} limit (1.0) exceeded: R=1.025, W=1.016, B=1.044
TC4 End (PS15)	B	23/02/2019 15:07:33	P_{ST} limit (1.0) exceeded: B=1.051
TC4 End (PS15)	R/W	27/02/2019 09:37:33	P_{ST} limit (1.0) exceeded: R=1.425, W=1.42

6.4.2. VOLTAGE

The logged voltage level data for the start and end of the TC4 feeder is shown from Figure 113 to Figure 118 in Appendix B.4. Table 13 below lists the recorded breach events during the logging period.

Table 13 | Feeder TC4 Voltage Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	VOLTAGE EVENT DETAILS/MAGNITUDE
TC4 End (PS15)	B	23/02/2019 15:07:33	Undervoltage limit (-6%) exceeded: B=221.63 V

6.4.3. FREQUENCY

The logged frequency data for the start and end of the TC4 feeder is shown in Figure 119 and Figure 120 in Appendix B.4. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.4.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the TC4 feeder is shown from Figure 121 to Figure 126 in Appendix B.4. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.4.5. HARMONICS

The logged harmonic data for the start and end of the TC4 feeder is shown from Figure 127 to Figure 134 in Appendix B.4. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 8 through to Figure 10. Given the temporary and random nature of the breaches, they are not deemed of any practical concern (i.e. not deemed as compliance issues).

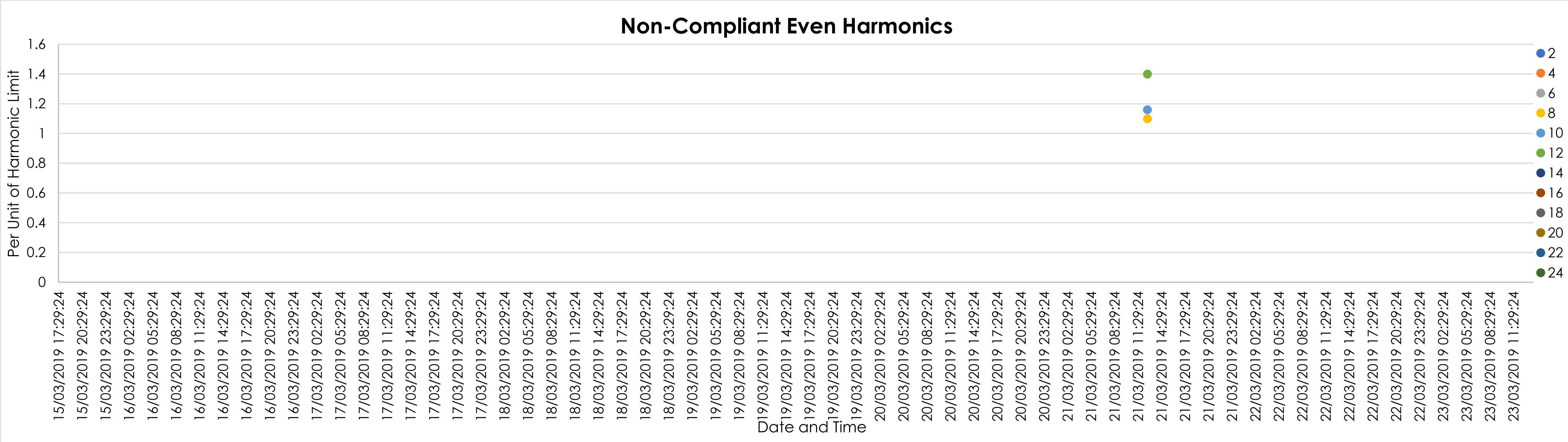


Figure 11 | TC4 Feeder (Start) - Non-Compliant Even Harmonics

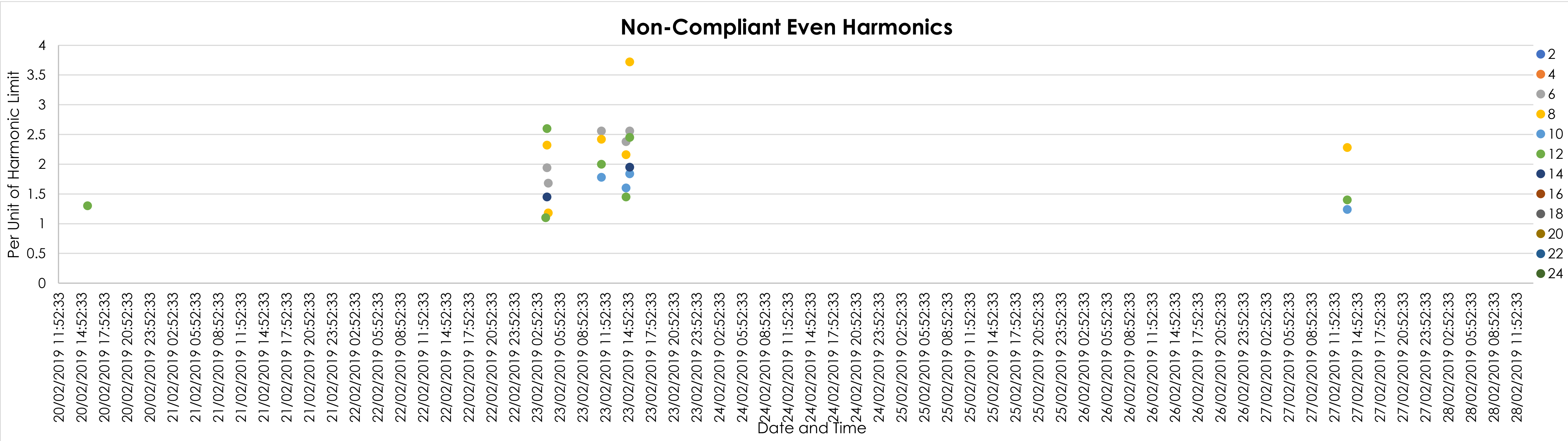


Figure 12 | TC4 Feeder (End) - Non-Compliant Even Harmonics

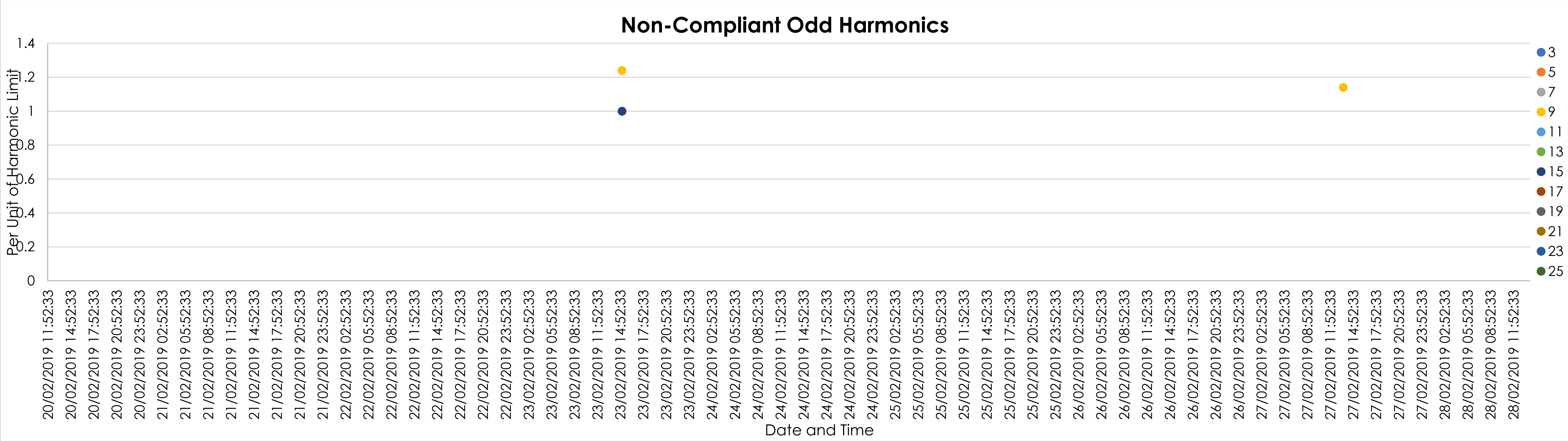


Figure 13 | TC4 Feeder (End) - Non-Compliant Odd Harmonics

6.5. FEEDER STS1

The PQ logger at the start of the STS1 feeder was installed at the PS94 Pardoo Street substation between 20/02/2019 and 26/02/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the STS1 feeder was installed at the PS25 Laver Street substation between 07/03/2019 and 15/03/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Lime Green), STS1 originates from the South Town substation.

6.5.1. FLICKER

The logged flicker data for the start and end of the STS1 feeder is shown from Figure 135 to Figure 140 in Appendix B.5. Table 14 below lists the recorded breach events during the logging period.

Table 14 | Feeder STS1 Flicker Breach Event Details

LOCATION	PHASE(S)	DATE AND TIME	FLICKER EVENT DETAILS/MAGNITUDE
STS1 Start (PS94)	R/W/B	23/02/2019 04:10:00	P_{ST} limit (1.0) exceeded: R=1.111 W=1.086, B=1.135

6.5.2. VOLTAGE

The logged voltage level data for the start and end of the STS1 feeder is shown from Figure 141 to Figure 146 in Appendix B.5. There were no noted voltage limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.5.3. FREQUENCY

The logged frequency data for the start and end of the STS1 feeder is shown in Figure 147 and Figure 148 in Appendix B.5. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.5.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the STS1 feeder is shown from Figure 149 to Figure 154 in Appendix B.5. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.5.5. HARMONICS

The logged harmonic data for the start and end of the STS1 feeder is shown from Figure 155 to Figure 162 in Appendix B.5. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 14 and Figure 15. Given the temporary and random nature of the breaches, they are not deemed of any practical concern (i.e. not deemed as compliance issues).

APD ENGINEERING

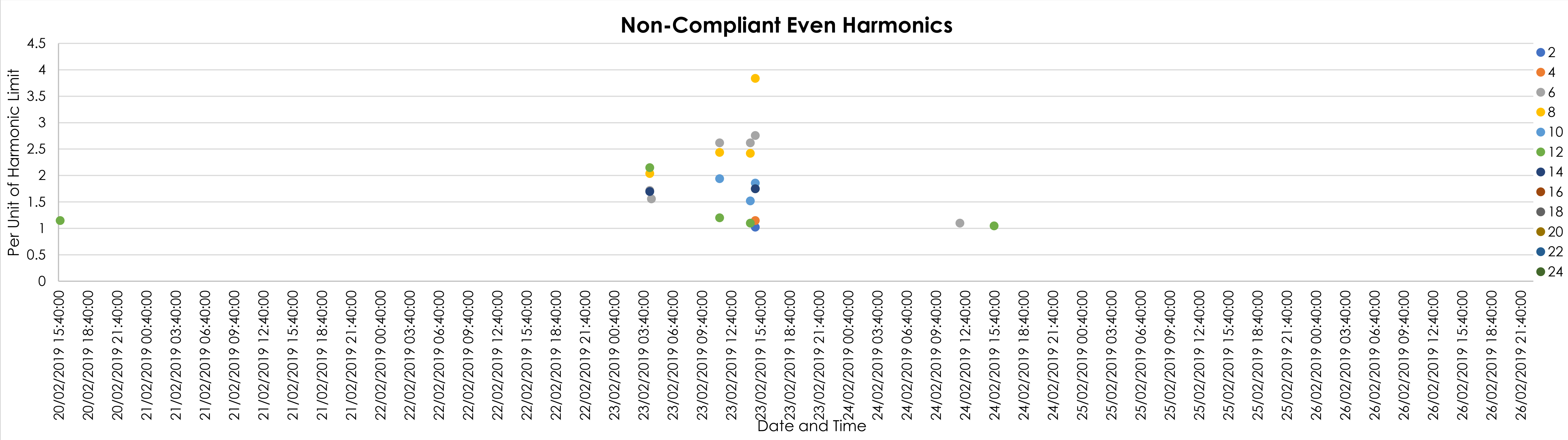


Figure 14 | STS1 Feeder (Start) - Non-Compliant Even Harmonics

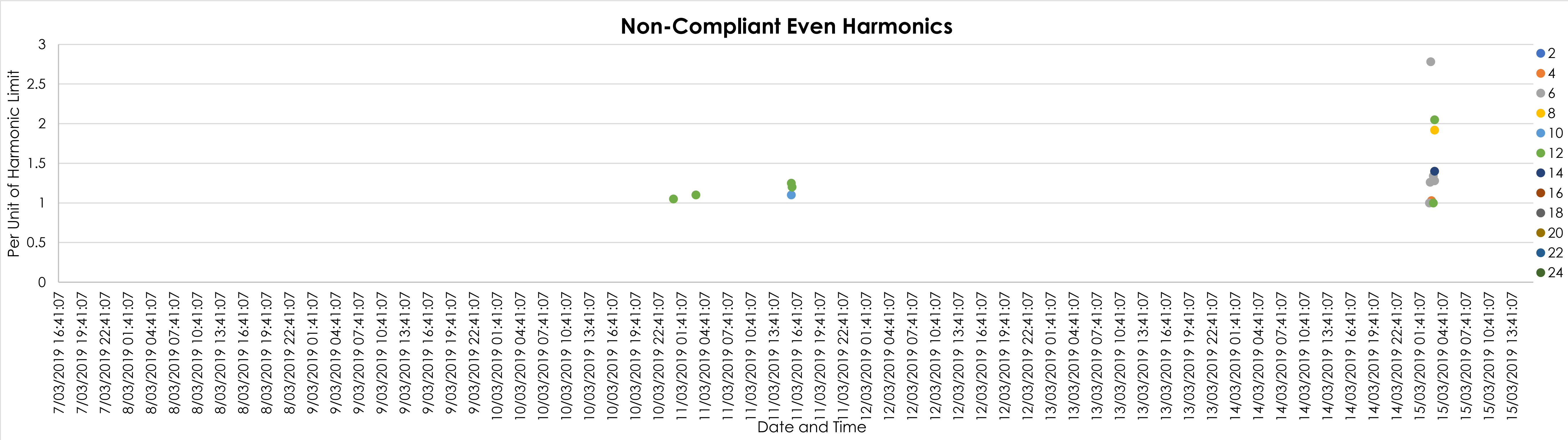


Figure 15 | STS1 Feeder (End) - Non-Compliant Even Harmonics

6.6. FEEDER STS2

The PQ logger at the start of the STS2 feeder was installed at the PS60 Forrest Avenue substation between 28/03/2019 and 04/04/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the STS2 feeder was installed at the PS70 Jabbarup Crescent Park substation between 27/02/2019 and 07/03/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Grey), STS2 originates from the South Town substation.

6.6.1. FLICKER

The logged flicker data for the start and end of the STS2 feeder is shown from Figure 163 to Figure 168 in Appendix B.6. There were no noted flicker limit events causing a breach of the Code's limits (i.e. full compliance with the Code requirements).

6.6.2. VOLTAGE

The logged voltage level data for the start and end of the STS2 feeder is shown from Figure 169 to Figure 174 in Appendix B.6. There were no noted voltage limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.6.3. FREQUENCY

The logged frequency data for the start and end of the STS2 feeder is shown in Figure 175 and Figure 176 in Appendix B.6. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.6.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the STS2 feeder is shown from Figure 177 to Figure 182 in Appendix B.6. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.6.5. HARMONICS

The logged harmonic data for the start and end of the STS2 feeder is shown from Figure 183 to Figure 190 in Appendix B.6. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 16 and Figure 17. Similar to Feeders TC3, TC4 and STS1, the majority of the non-compliant events on Feeder STS2 appear to be 6th, 8th and 12th order harmonics, however given the temporary and random nature of the breaches, they are not deemed of any practical concern (i.e. not deemed as compliance issues).

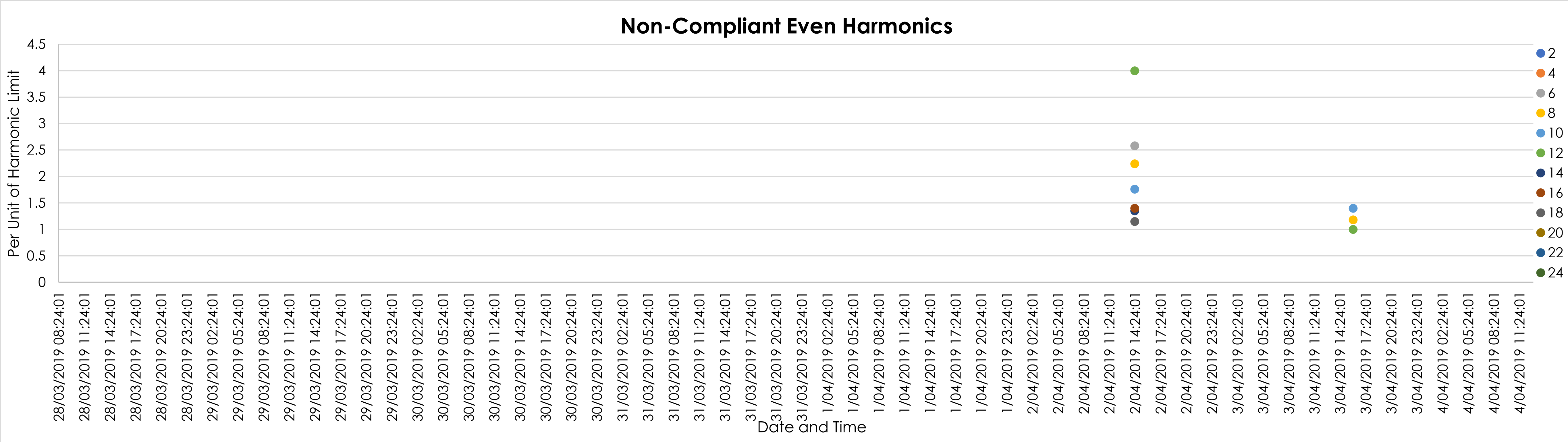


Figure 16 | STS2 Feeder (Start) - Non-Compliant Even Harmonics

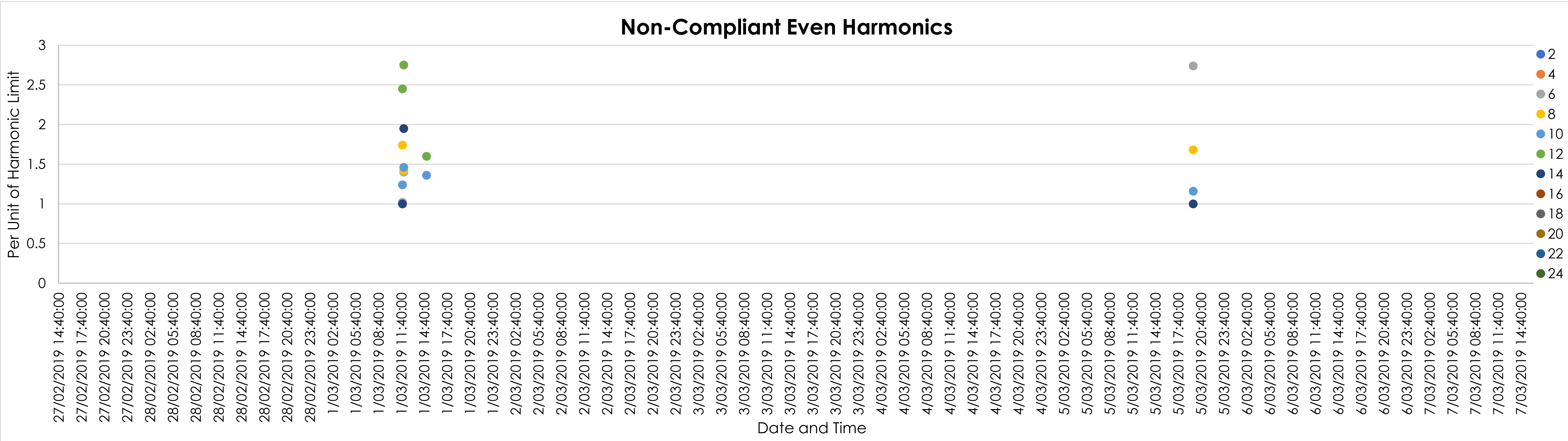


Figure 17 | **STS2 Feeder (End) - Non-Compliant Even Harmonics**

6.7. FEEDER STS4

The STS4 Feeder has not been audited under previous Annual Compliance Reports, therefore no comments have been made on comparative power quality. The PQ logger at the start of the STS4 feeder was installed at the PS111 Hilditch Avenue substation between 08/03/2019 and 16/03/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the STS4 feeder was installed at the PS44 Iron Ore Parade substation between 08/03/2019 and 16/03/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Red), STS4 originates from the South Town substation.

6.7.1. FLICKER

The logged flicker data for the start and end of the STS4 feeder is shown from Figure 191 to Figure 196 in Appendix B.7. There were no noted flicker limit events causing a breach of the Code's limits (i.e. full compliance with the Code requirements).

6.7.2. VOLTAGE

The logged voltage level data for the start and end of the STS4 feeder is shown from Figure 197 to Figure 202 in Appendix B.7. There were no noted voltage limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.7.3. FREQUENCY

The logged frequency data for the start and end of the STS4 feeder is shown in Figure 203 and Figure 204 in Appendix B.7. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.7.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the STS4 feeder is shown from Figure 205 to Figure 210 in Appendix B.7. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.7.5. HARMONICS

The logged harmonic data for the start and end of the STS4 feeder is shown from Figure 211 to Figure 218 in Appendix B.7. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 18 through to Figure 20. Figure 19 shows a significant number of non-compliant odd harmonics on the STS4 Start Feeder (PS44), of which the majority are 21st order harmonic with several 15th order harmonics also providing non-compliance events. It is observed that the magnitude of the non-compliances appears to follow a typical daily demand pattern, with the most onerous events occurring in the early afternoon and little or no events occurring at night.

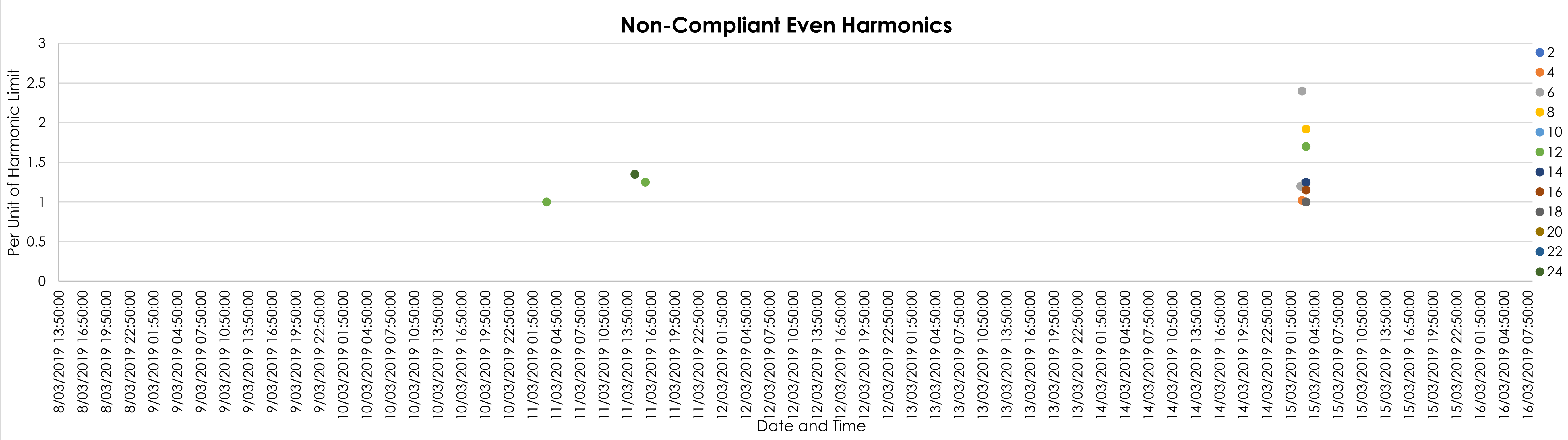


Figure 18 | STS4 Feeder (Start) - Non-Compliant Even Harmonics

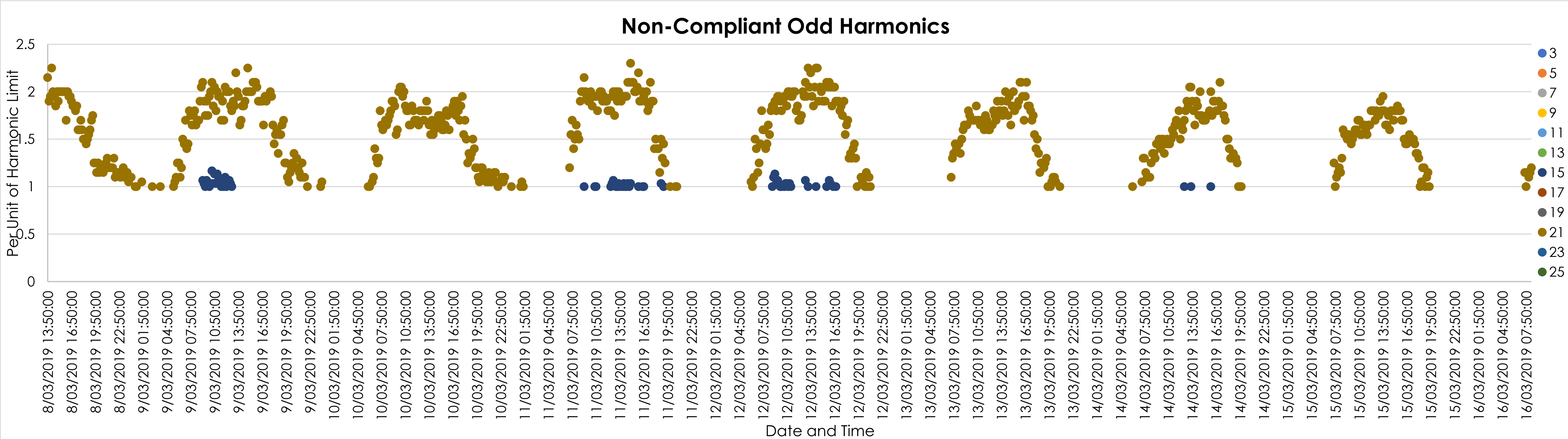


Figure 19 | STS4 Feeder (Start) - Non-Compliant Odd Harmonics

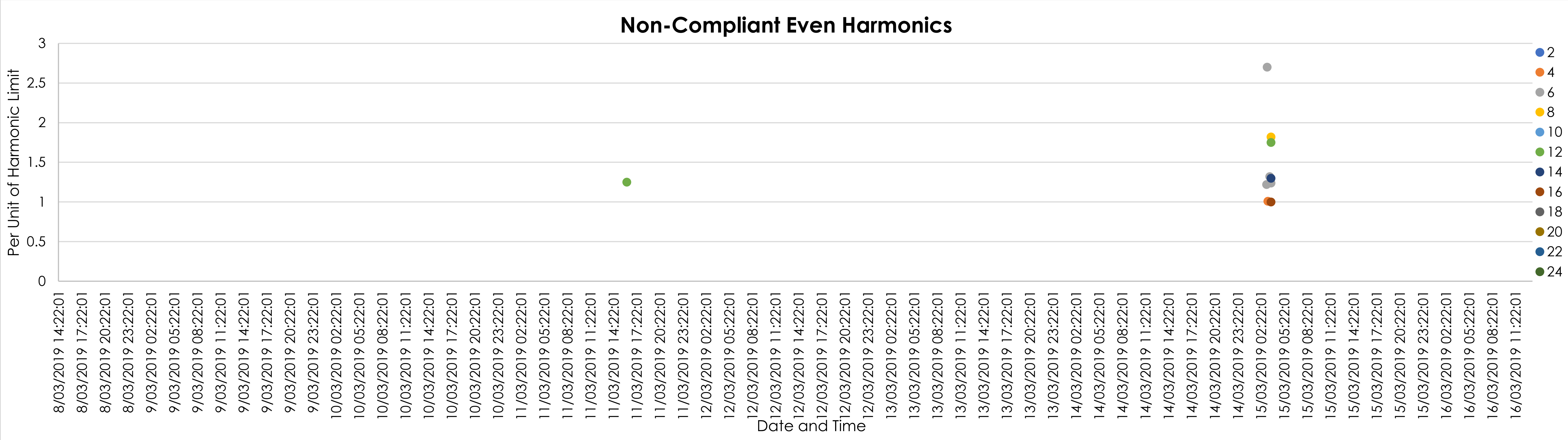


Figure 20 | STS4 Feeder (End) - Non-Compliant Even Harmonics

6.8. FEEDER STS6

The PQ logger at the start of the STS6 feeder was installed at the PS129 Moondoorow Street substation between 08/03/2019 and 16/03/2019, satisfying the seven day minimum logging duration requirement. The PQ logger at the end of the STS6 feeder was installed at the PS122 Administration substation between 08/03/2019 and 16/03/2019, satisfying the seven day minimum logging duration requirement. As shown in Figure **1** (Yellow), STS6 originates from the South Town substation.

6.8.1. FLICKER

The logged flicker data for the start and end of the STS6 feeder is shown from Figure 219 to Figure 224 in Appendix B.8. There were no noted flicker limit events causing a breach of the Code's limits (i.e. full compliance with the Code requirements).

6.8.2. VOLTAGE

The logged voltage level data for the start and end of the STS6 feeder is shown from Figure 225 to Figure 230 in Appendix B.8. There were no noted voltage limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.8.3. FREQUENCY

The logged frequency data for the start and end of the STS6 feeder is shown in Figure 231 and Figure 232 in Appendix B.8. There were no recorded frequency limit events causing the voltage level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.8.4. VOLTAGE THD

The logged voltage THD level data for the start and end of the STS6 feeder is shown from Figure 233 to Figure 238 in Appendix B.8. There were no noted voltage limit events causing the voltage THD level to breach the Code's limits (i.e. full compliance with the Code requirements).

6.8.5. HARMONICS

The logged harmonic data for the start and end of the STS6 feeder is shown from Figure 239 to Figure 246 in Appendix B.8. A summary of non-compliant harmonics and the scale of non-compliances is shown in Figure 21 and **Figure 22**. Given the temporary and random nature of the breaches, they are not deemed of any practical concern (i.e. not deemed as compliance issues).

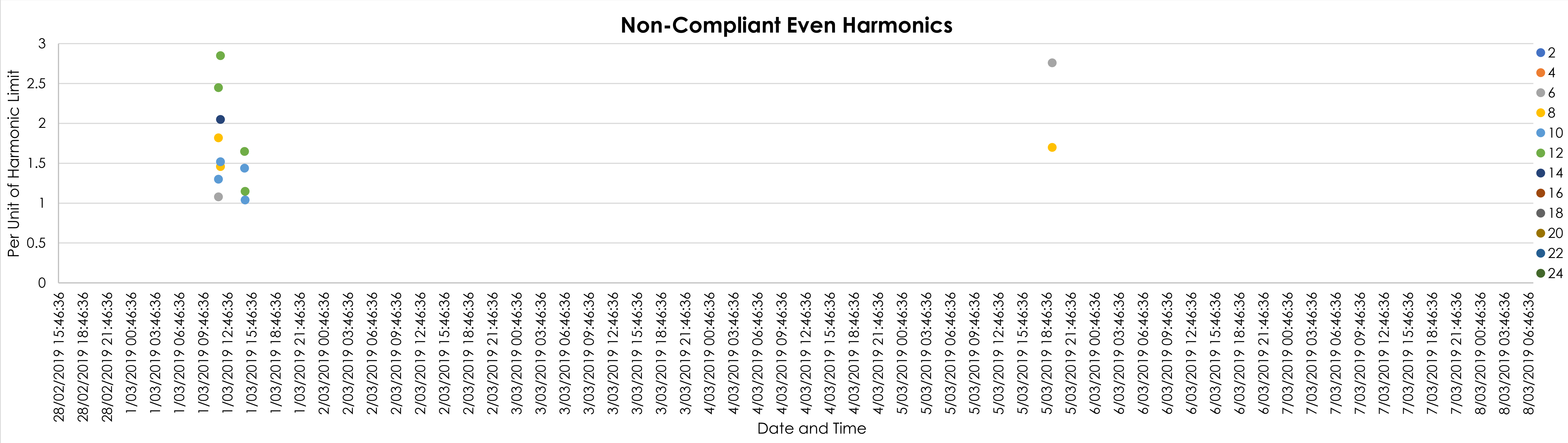


Figure 21 | STS6 Feeder (Start) - Non-Compliant Even Harmonics

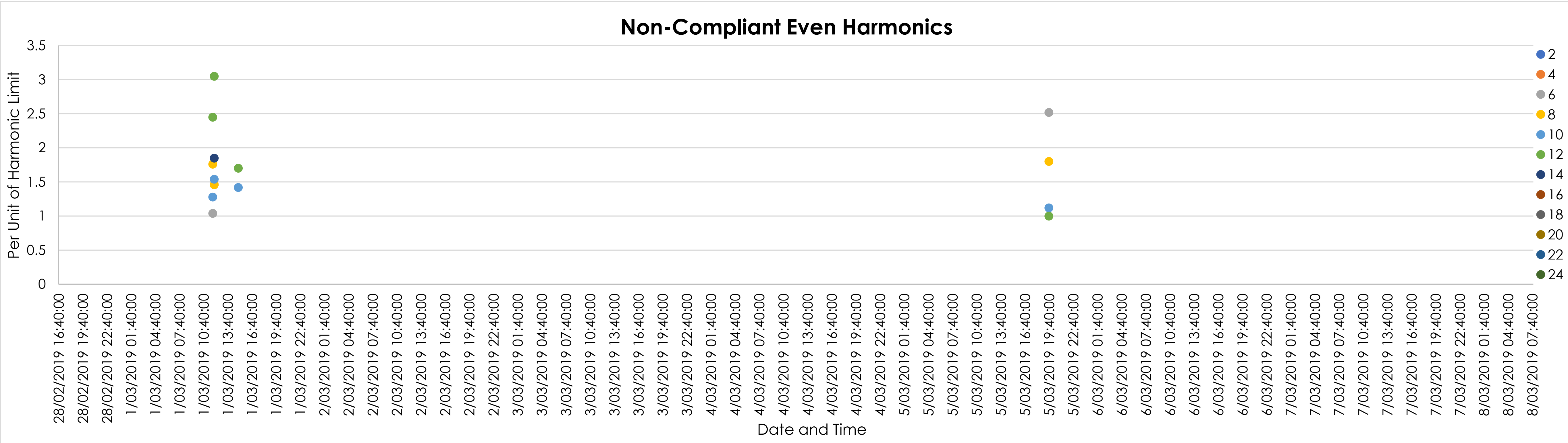


Figure 22 | STS6 Feeder (End) - Non-Compliant Even Harmonics

7. RESPONSE TO THE CODE REQUIREMENTS

This section contains all of the information required for compliance reporting as detailed in the Code "Schedule 1 – Information to be published" and "Part 2 – Quality and reliability standards".

7.1. QUALITY AND RELIABILITY STANDARDS (PART 2)'

7.1.1. FLICKER (PART 2 DIVISION 1 QUALITY STANDARDS SECTION 6(2))

The voltage fluctuations (flicker) of electricity supplied must not exceed the compatibility levels for long-term and short-term flicker as described in Section 5.1.1. Table 15 presents the results for the previous three reporting periods together with the 2018/2019 result.

Given the results presented, a relative deterioration of the flicker issues is observed over the 2018/2019 FY compared to the logging periods from the previous three years. If similar or worsened issues are measured in next year, then further investigations are recommended to identify and mitigate the root-cause.

Table 15 | Total number of flicker level breaches

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total short-term breaches P_{ST}	1	0	8	17
Total long-term breaches P_{LT}	0	0	0	4

7.1.2. VOLTAGE LEVEL (PART 2 DIVISION 2 QUALITY STANDARDS SECTION 8 NOTE(A))

The following information is not required as part of the reporting requirements of the Code. It has been included here to provide a more complete indication of the network power supply quality. In accordance with AS 3000:2018, the voltage levels of the electrical network must be maintained between +10%/-6% of the nominal 240 V single-phase supply voltage.

Table 16 presents the results for the previous four reporting periods. Within the 2018/2019 FY logging period eight separate voltage limit breaches were recorded, all of which were undervoltage events (below -6% of 240 V). Given the negative trend observed in the last 2 years, it is recommended that this parameter is monitored more closely in the coming year and if the problem persists, an investigation should be made into the possible causes for mitigation purposes.

Table 16 | Total number of voltage level breaches

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total Voltage limit breaches	0	0	4	8

7.1.3. FREQUENCY (PART 2 DIVISION 2 QUALITY STANDARDS SECTION 8 NOTE(B))

The Electricity Act of 1945 Section 25(1)(d) states that the frequency of electricity supplied must be maintained at ±2.5% of 50 cycles per second. This information is not required as part of the reporting requirements of the Code, but it has been included here to provide a more complete indication of supply PQ.

Table 17 presents the results for the previous three reporting periods together with the 2018/2019 results. Within the 2018/2019 FY logging period a single over-frequency event of 64.929 Hz was recorded (start of feeder TC2) however due to the isolated and random nature of the event, the electricity supply is expected to fall within the limits given above.

Table 17 | Total number of frequency level breaches

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total Frequency limit breaches	0	0	0	1

7.1.4. HARMONICS (PART 2 DIVISION 1 QUALITY STANDARDS SECTION 7)

Within the Code, there are two measures for assessing the power quality of the Newman network. The two measures are:

1. Assessment of individual harmonics and a comparison of their magnitudes against the table in Part 2 Division 1 Section 7 of the Code; and
2. Assessment of the calculated Voltage Total Harmonic Distortion (U-THD) and a comparison of its magnitude with the Code's compliant value of 8%.

7.1.4.1. INDIVIDUAL VOLTAGE HARMONICS

Individual, non-compliant harmonics for each respective feeder are presented in Section 6.

7.1.4.2. VOLTAGE TOTAL HARMONIC DISTORTIONS

The voltage harmonic distortion levels of electricity supplied must not exceed the U-THD limit of 8% stated in Part 2, Division 1, Section 7 of the Code. Table 18 presents the results for the previous three reporting periods together with the 2018/2019 result. Within the 2018/2019 FY logging period, one event was recorded where the maximum U-THD was greater than the 8% limit. With the exception of the single breach, the average U-THD recorded within the same logging period was consistently well below the 8% limit.

Table 18 | Total number of total harmonic distortion level breaches

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total U-THD limit breaches	0	0	0	1

7.2. REMEDIAL ACTIONS TAKEN FOR BREACHES (SCHEDULE 1 ITEM 4(B))

Newman BHPSA is found to have pro-active approach toward establishing and executing asset replacement and improvement programs to sustain and improve power quality and reliability across the Newman Township.

To ensure compliance with Australian regulations, BHPSA have undertaken annual PQ logging on the 11 KV supply feeders originating from both the South Town and Township substations during the summer period. Improvements are implemented based on the PQ logging data results and any complaints received from customers related to power quality issues.

Asset upgrades include:

- Continued and finalised works on the major equipment upgrades at the Township Substation including the replacement of the two ageing 66/11kV power transformers and the neutral earth resistors.
- Proactive upgrade of an overhead section of low voltage powerline along Mindarra Drive to an underground section to improve the safety to public within area due to lower height clearances on this section.
- Continuation of ad-hoc improvements as a result of investigations, e.g., replacement of ageing or defective pole top distribution transformers and pad-mount substations. Namely, replacement of transformer T7 and pad-mount substation PS61 due to End of Life for the assets and replacement of an ageing low voltage switchboard at PS113 'Fortescue Flats'.
- Planning for the replacement of sections of HV overhead line with HV underground cabling within the Township of Newman, namely an upcoming project (previously scheduled for the 2018/19 FY period, budgeting has pushed the project to 2019/20 FY period) for the upgrade of a main road overhead crossing to prevent oversize loads accidentally connecting with the powerline.
- Investigation and 'pilot project' installation of permanent SEL735 Advanced Power Quality and Revenue Meters at select pad-mount substations to improve the annual logging process and provide year round access to PQ data including harmonics.

7.3. SUPPLY INTERRUPTED (SCHEDULE 1 ITEM 5)

Schedule 1 of the Code gives the information to be published within the annual compliance report. The provisions of Item 5 requires that the following information be published:

> *"The number of premises of small use customers the supply of electricity to which has been interrupted:*
>
> > *(a) for more than 12 hours continuously; or*
> >
> > *(b) more than the permitted number of times, as that expression is defined in section 12(1)*,*
>
> *and in the case of interruptions referred to in paragraph (a), the number of interruptions and the length of each interruption."*

*Section 12(1) of the Code defines 'permitted number of times' as nine times (for Perth CBD or urban areas) or 16 times (for small use customers in other areas).

7.3.1. INTERRUPTIONS EXCEEDING 12 HOURS

There were no interruptions exceeding 12 hours for small customers recorded for 2018/2019 FY.

Table 19 | Total number of premises of small customers interrupted continuously for more than 12 hours

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total number of premises that experienced interruptions more than 12 hour	0	1	0	0

7.3.2. INTERRUPTIONS EXCEEDING THE PERMITTED NUMBER OF TIMES

The permitted number of times that a customer connection can be disconnected from the electricity supply within the preceding year (defined as the period of 12 months ending on 30 June) is given as 16 as per Section 12(1) of the Code.

There were no customers disconnected more than 16 times as observed in the BHP outage logs.

Table 20 | Total number of premises that experienced >16 interruptions within the preceding year

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total number of premises that experienced more than 16 interruptions	0	0	0	0

7.4. NUMBER OF COMPLAINTS RECEIVED (SCHEDULE 1 ITEMS 6 AND 10)

Division 2, Section 25(1) of the Code defines complaint as a complaint that a provision of Part 2, or of an instrument made under section 14(3), has not been, or is not being, complied with. Table 21 presents the results for the previous three reporting periods together with the 2018/2019 FY results.

No complaints relating to power quality were received in 2018/2019 FY.

Table 21 | Total number of formal complaints lodged to BHPSA

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total number of formal complaints received	0	0	0	0

7.5. COMPLAINTS RECEIVED IN EACH DISCRETE AREA (SCHEDULE 1 ITEMS 7 AND 10)

The township of Newman is supplied form an integrated network and therefore there are no discrete areas to be reported.

7.6. TOTAL AMOUNT SPENT ADDRESSING COMPLAINTS (SCHEDULE 1 ITEMS 8 AND 10)

There has been no technical complaint over the 2018/19 FY that required BHP's action.

7.7. NUMBER AND TOTAL AMOUNT OF PAYMENTS MADE (SCHEDULE 1 ITEMS 9 AND 10)

Sections 18 and 19 of the Code stipulates that failure on the part of the electricity distributor to provide required notice for either a planned interruption or an interruption exceeding 12 hours to a small use customer shall result in a financial payment.

Table 22 presents the summary of payments made to small use customers over the three previous reporting periods, as well as the 2018/2019 FY period.

Table 22 | Summary of payments made under Sections 18 and 19

DESCRIPTION	REPORTABLE PERIOD			
	2015/2016	2016/2017	2017/2018	2018/2019
Total number of payments	0	0	0	0
Total amount of payouts in AUD ($)	0	0	0	0

7.8. RELIABILITY OF SUPPLY (SCHEDULE 1 ITEM 11)

The provisions of Schedule 1, Item 11 of the Code requires that the following information to be published:

> *"For each discrete area:*
>
> *(a) the average length of interruption of supply to customer premises expressed in minutes;*
>
> *(b) the average number of interruptions of supply to customer premises;*
>
> *(c) the average percentage of time that electricity has been supplied to customer premises; and*
>
> *(d) the average total length of all interruptions of supply to customer premises expressed in minutes."*

In the context of this report, the township of Newman is considered the *discrete area*. The BHPSA 2018/2019 FY fault outage data presented within Appendix C has been applied in determining the parameters described above and presented further in the following sub-sections.

7.8.1. AVERAGE INTERRUPTION (SCHEDULE 1 ITEMS 11(A), 12 AND 13)

Table 23 presents the average length of a supply interruption to small use customer connections affected by a fault within the Newman township electrical network, also known as the CAIDI described in Section 5.4.1, over the three previous reporting periods as well as the 2018/2019 FY period.

Table 23 | Summary of average interruption length to affected customers (CAIDI)

DESCRIPTION	REPORTABLE PERIOD				AVERAGE
	2015/2016	2016/2017	2017/2018	2018/2019	
Average interruption length – CAIDI (minutes)	102	53	33	141	82

7.8.2. AVERAGE NUMBER OF INTERRUPTIONS (SCHEDULE 1 ITEMS 11(B), 12 AND 13)

Table 24 presents the average number of interruptions to small use customer connections within the Newman township electrical network, also known as the SAIFI described in Section 5.4.2, over the three previous reporting periods as well as the 2018/2019 FY period.

Table 24 | Summary of average number of interruptions (SAIFI)

DESCRIPTION	REPORTABLE PERIOD				AVERAGE
	2015/2016	2016/2017	2017/2018	2018/2019	
Average number of interruptions – SAIFI	1.64	1.53	1.07	2.66	1.73

7.8.3. AVERAGE TIME PERCENTAGE SUPPLIED (SCHEDULE 1 ITEMS 11(C), 12 AND 13)

Table 25 presents the average percentage of time that electricity has been supplied to small use customer connections, also known as the ASAI described in Section 5.4.3, over the three previous reporting periods as well as the 2018/2019 FY period.

Table 25 | Summary of average percentage of time supplied (ASAI)

DESCRIPTION	REPORTABLE PERIOD				AVERAGE
	2015/2016	2016/2017	2017/2018	2018/2019	
Average percentage of time supplied – ASAI (%)	99.97	99.98	99.99	99.93	99.97

7.8.4. AVERAGE LENGTH OF ALL INTERRUPTIONS (SCHEDULE 1 ITEMS 11(D), 12 AND 13)

Table 26 presents the average length of a supply interruption to any single small use customer connection within the Newman township electrical network, also known as the SAIDI described in Section 5.4.4, over the three previous reporting periods as well as the 2018/2019 FY period.

Table 26 | Summary of average interruption length to all customers (SAIDI)

DESCRIPTION	REPORTABLE PERIOD				AVERAGE
	2015/2016	2016/2017	2017/2018	2018/2019	
Average interruption length – SCAIDI (minutes)	168	81	35	376	167

7.9. PERCENTILE VALUES (SCHEDULE 1 ITEMS 14 AND 15)

This section outlines the response to Schedule 1, Items 14 and 15 of the Code. An extract from the Code requirements is shown below:

> *Item 14: "For customer premises in each discrete area, an estimate of the 25th, 50th, 75th, 90th, 95th, 98th and 100th percentile values of —*
>
> > *(a) the average length of interruption referred to in item 11(a);*
> >
> > *(b) the number of interruptions; and*
> >
> > *(c) the total length of interruptions."*
>
> *Item 15: "For each category of information in item 14(a), (b) and (c), a graph showing the distribution of customer premises across the range of that category."*

7.9.1. AVERAGE INTERRUPTION (CAIDI) – PERCENTILE

Table 27 presents the percentile distribution spread for the average length of interruptions to affected small use customers (CAIDI) within the Newman Township for the 2018/2019 FY logging period.

Table 27 | CAIDI Percentile Distribution 2018/2019 FY

DESCRIPTION	PERCENTILE						
	25TH	50TH	75TH	90TH	95TH	98TH	100TH
Average Length of Interruption (CAIDI)	100	76	76	76	76	76	141

7.9.2. NUMBER OF INTERRUPTIONS (SAIFI) – PERCENTILE

Table 28 presents the percentile distribution spread for the average number of interruptions to small use customers (SAIFI) within the Newman Township for the 2018/2019 FY logging period.

Table 28 | SAIFI Percentile Distribution 2018/2019 FY

DESCRIPTION	PERCENTILE						
	25TH	50TH	75TH	90TH	95TH	98TH	100TH
Average Number of Interruptions (SAIFI)	0.34	0.66	0.66	0.66	0.66	0.66	2.66

7.9.3. AVERAGE LENGTH OF ALL INTERRUPTIONS (SAIDI) – PERCENTILE

Table 29 presents the percentile distribution spread for the average length of all interruptions to a small use customer (SAIDI) within the Newman Township for the 2018/2019 FY logging period.

Table 29 | SAIDI Percentile Distribution 2018/2019 FY

DESCRIPTION	PERCENTILE						
	25TH	50TH	75TH	90TH	95TH	98TH	100TH
Average Length of All Interruptions (SAIDI)	34	50	50	50	50	50	376

8. CONCLUSION

This report addresses all relevant parts pertaining to Newman's 11 kV supply network and the reportable requirements as per Part 2 and Schedule 1 of the Code.

With regards to the site measurements, the *average* values of electrical parameters were logged over a period of seven days, at 10-minutes intervals. PQ indices were then calculated and found, in large, within the limits stipulated by the Code. That is, the *averages* of the following parameters are proven to meet the Code's requirements:

- *Voltage Flicker (short- and long-term criteria);*
- RMS Voltage Magnitude;
- Power System Frequency; and
- *Voltage Total Harmonic Distortion (U-THD)*.

The following compliance issues were identified:

- Voltage Flicker: An increase in the number of short-term and long-term voltage fluctuation limit breaches (17 short-term and four long-term breaches) described in AS61000:2001 was recorded compared to the logging periods for previous three years. The most onerous breaches were observed on the TC1, TC2, TC3 and TC4 feeders, with eight separate breach events recorded on the TC2 feeder in particular.
- RMS Voltage Magnitude: A relative increase in the number of voltage level breaches (eight undervoltage breaches) were observed compared to the logging periods for the previous three years. Given the temporary and random nature of the breaches, it is not deemed of a practical concern at this stage, but it is recommended that this parameter be monitored over the coming years.
- Power System Frequency: A single over-frequency breach of the limits described in the Electricity Act of 1945 Section 25(1)(d) was recorded during the logging period. As this event appears to be isolated and constitutes a very small fraction (less than 0.1%) of the total measurement period, it is not deemed of a practical concern at present.
- U-THD: A single U-THD breach of the limits described in Part 2, Division 1, Section 7 of the Code was recorded during the logging period. With the exception of the single breach, the average U-THD level recorded on all feeders was consistently below the required limit.
- The recorded individual order harmonics showed a number of temporary and random breaches on all feeders that are not deemed of a practical concern; however, it was observed that the majority of breaches were 6^{th}, 8^{th} and 12^{th} order harmonics. A large number of 15^{th} and 21^{st} order harmonic level breaches were recorded on the STS4 Feeder Start (PS44). The magnitude of these breaches appears to follow a typical daily demand pattern, and it is recommended that the cause of these breaches is investigated.

Reportable parameters for Newman Township Electricity Supply over the 2018/19 FY (as outlined in the 'Schedule 1' of the Code) are presented below:

- *>12 hour interruptions:* No interruptions were recorded to have exceeded 12 hours.
- No *small use customer* was disconnected from the network more frequent than the Code's requirements (i.e., limit of 16 times).
- No complaints were received from customers during FY 2018/2019.
- The key reliability indices are calculated as listed below:
  - *Customer Average Interruption Duration Index (CAIDI)* of 114 minutes – CAIDI is the average outage duration that any given customer experience (i.e., the average restoration time).
  - *System Average Interruption Frequency Index (SAIFI)* of 2.66 interruptions – SAIFI is the number of interruptions that the customers experienced.
  - *Average Service Availability Index (ASAI)* of 99.93% – ASAI is the perceived availability of the network to the customers.
  - *System Average Interruption Duration Index (SAIDI)* of 376 minutes – SAIDI is the average outage duration for each customer served.

In summary, the metering data collected from the 16 locations throughout the Newman Township network indicate that the power quality is, in large, within the limits stipulated by the Code. It should be noted that although the overall reliability of the Newman Township supply appeared to have degraded when compared to the same reliability indices for previous FYs, the overall network performance is still considered to be satisfactory. The relative deterioration in reliability indices is largely attributed to the Blackout events outside of Newman Township's control. As such, this report finds the reliability and quality of the supply for Newman Township network in compliance with the Code's requirements, with further monitoring of areas of the network recommended to ensure improved quality and reliability in the upcoming years.

APPENDIX A. PQ LOGGING DEVICE (HIOKI 3198)

Refer to the attached.

HIOKI

POWER QUALITY ANALYZER PW3198

Power Measuring Instruments

Record and Analyze Power Supply Problems Simultaneously with a Single Unit

The New World Standard for Power Quality Analysis

Never Miss the Moment
- Detect power supply problems and perform onsite troubleshooting
- Do preventive maintenance to avert accidents by managing the power quality

CAT IV-600V Safety Standard
- Meets the CAT IV safety rating required to check an incoming power line
- Safe enough to measure up to 6,000Vpeak of transient overvoltage

Easy Setup Function with PRESETS
- Just select the measurement course, wiring, and clamps
- Automatic one-step setup based on measurement conditions

Compliant with New International Standards
- International power quality measurement standard IEC 61000-4-30 Edition 2 Class A
- High precision with a basic voltage measurement accuracy of 0.1%

ISO 9001 JMI-0216

ISO14001 JQA-E-90091

www.hioki.com

HIOKI company overview, new products, environmental considerations and other information are available on our website.

One Single Unit Can Solve All Your Power Supply Problems

The number of power supply problems is increasing as power systems are becoming more and more complicated - all due to the rising use of power electronics devices plus a growing installed base of large systems and distributed power supplies. The quickest way to approach these problems is to understand the situation quickly and accurately. The PW3198 Power Quality Analyzer is ready to effectively solve your power supply problems.

Troubleshooting

- ✔ Understand the actual power situation at the site where the problem is occurring (e.g., the equipment malfunction, failure, reset, overheating, or burning damage).
- ✔ Ideal for troubleshooting solar and wind power generation systems, EV charge stations, smart grids, tooling machines, OA equipment (e.g., computers, printers, and UPS), medical equipment, server rooms, and electrical equipment (e.g., transformers and phase-advancing capacitors).

Field Survey and Preventive Maintenance

- ✔ Perform long-term measurements of the power quality and study problems that are difficult to detect or that occur intermittently.
- ✔ Maintain electrical equipment and check the operation of solar and wind power generation systems.
- ✔ Manage the parameters with a control set point, such as a voltage fluctuation, flicker, and harmonic voltage.

Power (Load) Survey

- ✔ Study the power consumption and confirm system capacity before adding load.

Advanced Features for Safe, Simple, and Accurate Measurements

1 International Standard IEC61000-4-30 Edition 2 Class A

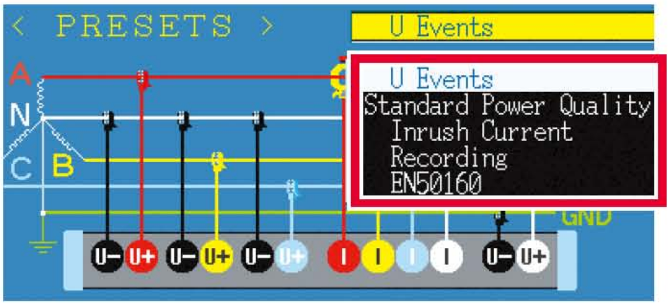
Class A is defined in the international standard IEC61000-4-30, which specifies compatibility with power quality parameters, accuracy, and standards to enable comparison and discussion of the measurement results of different measuring instruments.

The PW3198 is compliant with the latest IEC61000-4-30 Edition 2 Class A standard. The instrument can perform measurements in accordance with the standard, including continuous gapless calculation, methods to detect events such as dip, swell, and instantaneous power failure, and time synchronization using the optional GPS box.

2 CAT IV-600V Safety

The PW3198 is compliant with the measurement category CAT IV - 600V and can also safely test the incoming lines for both single-phase and three-phase power supplies.

3 Easy to set up - Just select the measurement course and the PW3198 will do the rest

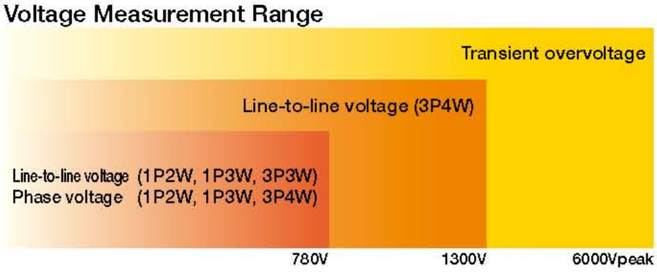


Simply choose the course based on the measurement objective and the necessary configurations will be set automatically.

U Events	Record voltage and frequency and detect errors simultaneously.
Standard Power Quality	Record voltage, current, frequency, and harmonic, and detect errors simultaneously.
Inrush current	Measure the inrush current.
Recording	Record only the TIME PLOT Data but do not detect errors.
EN50160	Perform measurements in accordance with EN50160.

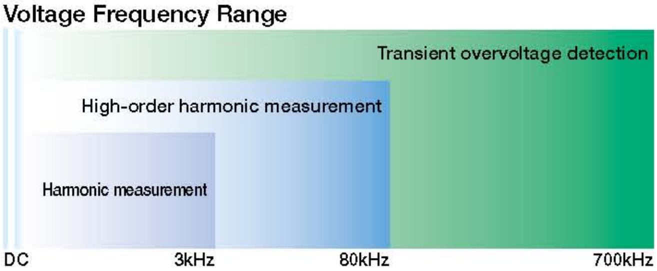
4 Highly Accurate, Broadband, Wide Dynamic Range Makes for Reliable Measurements

Voltage Measurement Range



Both low and high voltages can be measured in a single range.

Voltage Frequency Range



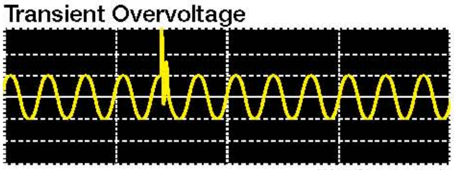
Wide range from DC voltage to 700 kHz

Basic Measurement Accuracy (50/60 Hz)

Voltage	±0.1% of nominal voltage
Current	±0.2% rdg. ±0.1% f.s. + Clamp-on sensor accuracy
Power	±0.2% rdg. ±0.1% f.s. + Clamp-on sensor accuracy

World's highest level of basic measurement accuracy. Extremely accurate voltage measurement without the need to switch ranges.

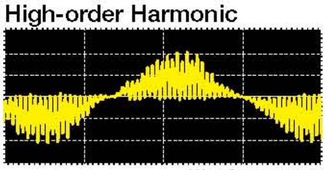
Transient Overvoltage



Waveform example

Transient overvoltage can also be measured in a range between the maximum 6,000 V and minimum 1 μs (2 MS/s).

High-order Harmonic



Waveform example

The PW3198 is the first power quality analyzer that can measure the high-order harmonic component of up to 80 kHz.

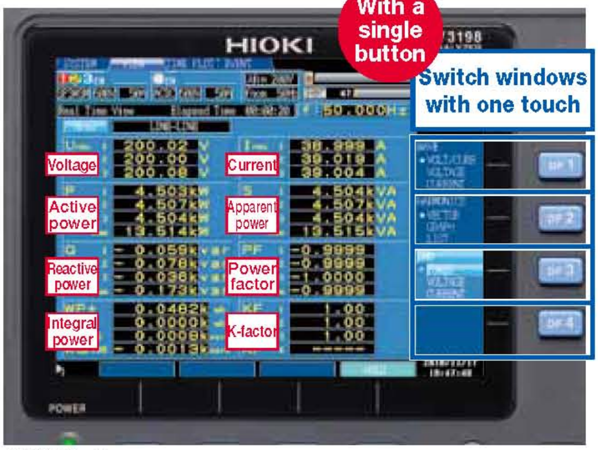
PW3198 Never Misses the Moment a Power Supply Failure Occurs

The PW3198 can measure all waveforms of power, harmonic, and error events simultaneously. When a problem occurs with the equipment or system on your site, the PW3198 will help you detect the cause of the problem early and solve it quickly. You can depend on the PW3198 to monitor all aspects of your power supplies.

Measure All Parameters at the **Same Time**

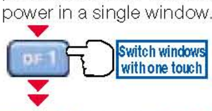
Acquire the Information You Need Quickly by Switching Pages (RMS Value)

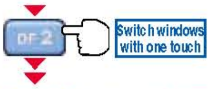
Just connect to the measurement line, and the PW3198 will simultaneously measure all parameters, such as power and harmonic. You can then switch pages to view the needed information immediately.

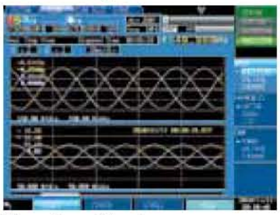


DMM Display

Display parameters such as voltage, current, power, power factor, and integral power in a single window.





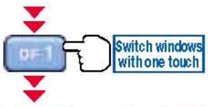


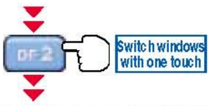
Waveform Display

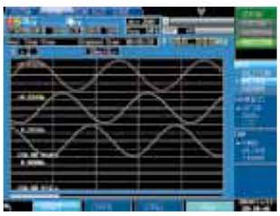
Display the voltage and current waveforms on channels 1 to 4 one above the other in a single window.

Vector Display

Display the measured value and vector of the voltage and current of each order harmonic.

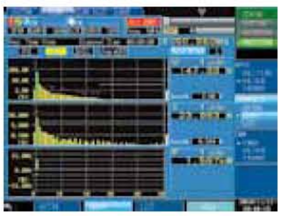






4-channel Waveform Display

Display the voltage and current waveforms on channels 1 to 4 individually.



Harmonic Bar Graph Display

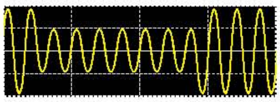
Display the RMS value and phase angle of harmonics from the 0th order to the 50th either in a graph or as numerical values.

Reliably Detect Power Supply Failures (Event)

To detect power supply failures, measurement does not need to be performed multiple times under different conditions. The PW3198 can always monitor and reliably detect all power supply failures for which detection is enabled.

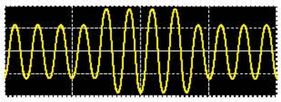
Transient Overvoltage (Impulse)

A transient overvoltage is generated by a lightning strike or a contact fault or closed contact of a circuit breaker and relay, and often causes a steep voltage change and a high voltage peak.



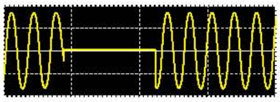
Voltage Dip (Voltage Drop)

Voltage drops for a short time as a result of large inrush current generated in the load by, for example, a starting motor.



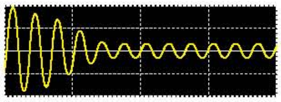
Voltage Swell (Voltage Rise)

A voltage swell is generated by a lightning strike or a heavily loaded power line being opened or closed, causing the voltage to rise instantaneously.



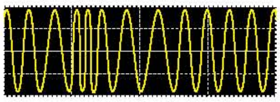
Interruption

The power supply stops instantaneously or for a short or long time because electrical power transmission is stopped as a result of a lightning strike, or because the circuit breaker is tripped by a power supply short circuit.



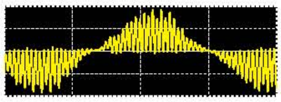
Inrush Current

A large current flows instantaneously at the moment electrical equipment, a motor, or similar devices are powered on.



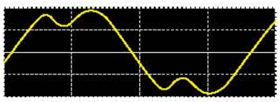
Frequency Fluctuations

An excessive increase or decrease of the load causes the operation of a generator to become unstable, resulting in frequency fluctuations.



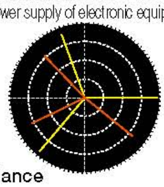
High-order Harmonic

Voltage and current waveforms are distorted by noise components generated by a semiconductor control device or the like installed in the power supply of electronic equipment.



Harmonic

Harmonic is generated by a semiconductor control device installed in the power supply of equipment, causing distortion of voltage and current waveforms.



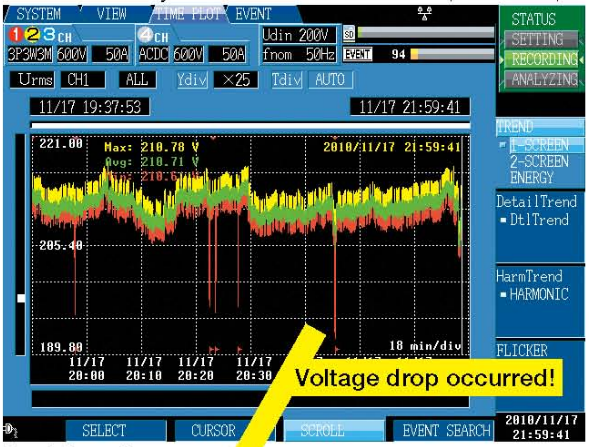
Unbalance

An increase or decrease in the load connected to each phase of the three-phase power supply or an unbalanced operation of equipment and devices causes the load of a particular phase to become heavy so that voltage and current waveforms are distorted, voltage drops, or negative phase sequence voltage is generated.

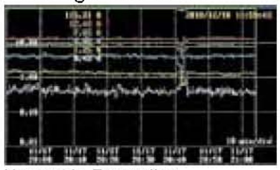
Simultaneous Recording of TIME PLOT Data and Event Waveforms

TIME PLOT Data — TIME PLOT Recording of All Parameters

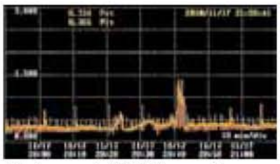
The PW3198 can simultaneously record 8,000 or more parameters, such as voltage, current, power, power factor, frequency, integral power, harmonic, and flicker, at the specified recording interval. The PW3198 never fails to capture the peak because it performs calculations continuously and records the maximum, minimum, and average values within the recording interval.



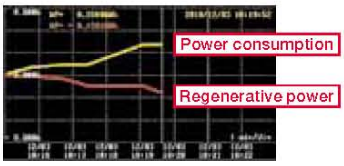
Trend Recording
(TIME PLOT Recording)



Harmonic Recording



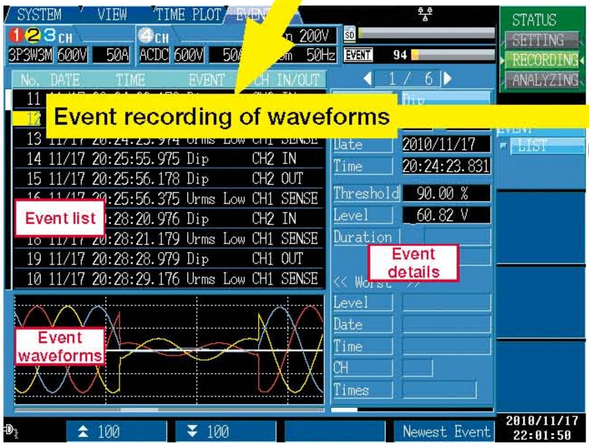
Flicker and ΔV10 Recording



Integral Power Recording

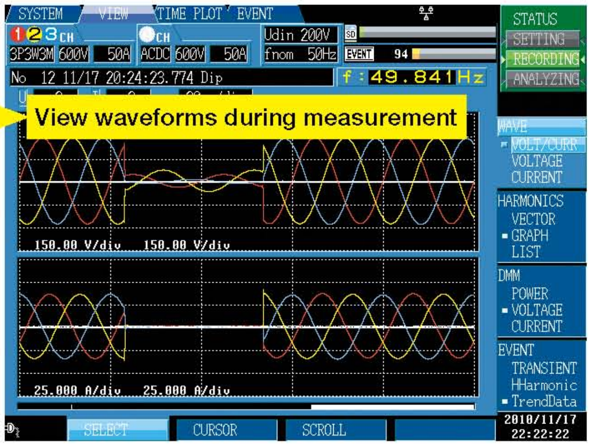
Event Waveforms — Capture up to 55,000 Instantaneous Waveforms of Power Supply Failures

The PW3198 can record up to 1,000 instantaneous waveforms of power supply failures (up to 55,000 when repeat recording is set to ON) while performing TIME PLOT recording.



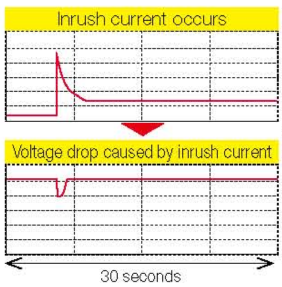
Event List

This list records instantaneous waveforms of power supply failures (events), such as a voltage drop or inrush current, along with the time or other information. Events are always monitored, regardless of the recording interval of the TIME PLOT recording.



Event Waveform

The PW3198 lets you view the instantaneous waveform (200 ms) of a power supply failure in the window.



RMS value changes over 30 seconds

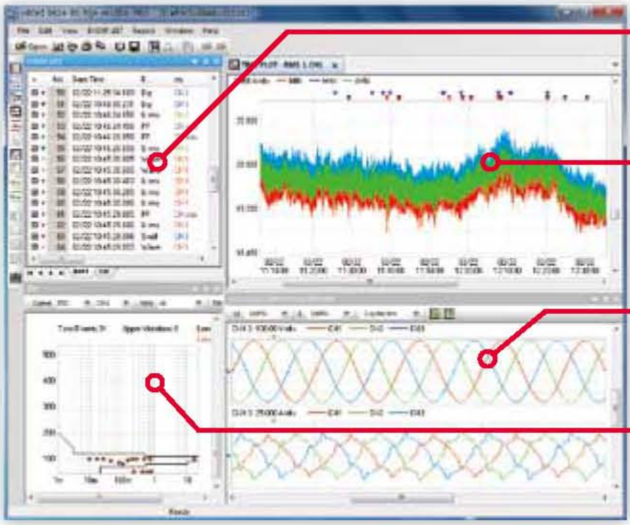
When a voltage drop or inrush current occurs, RMS value changes are recorded over 30 seconds simultaneously. This function can also be used to check the voltage drop caused by inrush current generated by the start of the motor.

Analyze Recorded Data with a PC Using Application Software 9624-50 PQA-HiVIEW PRO

Use Model 9624-50 PQA-HiVIEW PRO (version 2.00 or later) with a PC to analyze the data collected by the PW3198.

Viewer Function

Display and analyze the data recorded by the **PW3198 POWER QUALITY ANALYZER**.



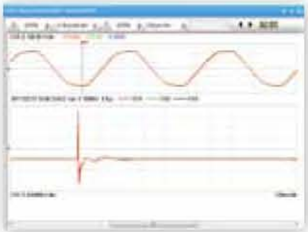
Event List Window
Display a list of power supply failures (events) that occurred.

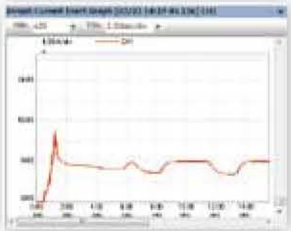
TIME PLOT Window
Display the TIME PLOT (recorded trend) data as well as changes in the voltage/current RMS values, harmonic, and many other parameters.

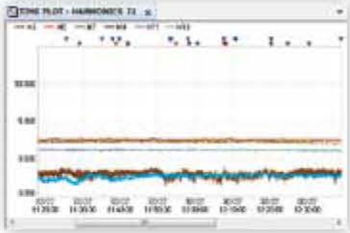
Event Waveform Window
Display the waveform of an event that occurred, plus the vector, harmonic, DMM, and instantaneous harmonic values.

ITIC Curve Display Window
Analyze the ITIC (CBEMA) curve (tolerance curve) used in the power quality standards in the United States.


Status Window


Transient Waveform Window


Inrush Current Event Graph Window

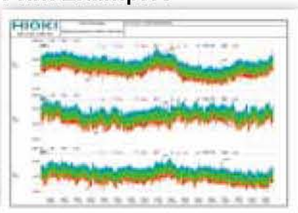

Harmonics TIME PLOT Window

Report Creation Function

Automatically and effortlessly create rich reports for compliance and record management.

Report output items: Voltage/current RMS value fluctuation graph, harmonic fluctuation graph, inter-harmonics fluctuation graph, flicker graph, integral power graph, demand graph, total harmonic voltage/current distortion rate list, EN50160 window (Overview, Harmonic, Measurement Results Category), worst case, transient waveform, maximum/minimum value list, all event waveforms/detailed list, and setup list

Print Examples


RMS Value Voltage Fluctuations


All Event Detailed List


TIME PLOT Recording of Parameters


EN50160

Other Functions

CSV Conversion of Measurement Data
Convert data in the range specified in the TIME PLOT window into CSV format and then save for further processing. The 9624-50 can also convert event waveforms into CSV format. Open CSV data using any commercially available spreadsheet software for advanced data management and analysis.

Even Analyze Data Recorded with Models 3196 and 3197 PQAs
Data recorded with the HIOKI 3196 and 3197 Power Quality Analyzers can also be analyzed.

Download Measurement Data via USB/LAN
Data in the SD card inserted in the PW3198 can be downloaded to a PC via USB or LAN.

EN50160 Display Function
EN50160 is a power quality standard for the EU. In this mode, evaluate and analyze power quality in accordance with the standard. You can display the Overview, Harmonic, and Measurement Results Category windows.

9624-50 Specifications

Delivery media	CD-R
Operating environment	AT-compatible PC
OS	Windows XP, Windows Vista (32-bit), Windows 7 (32/64-bit)
Memory	512 MB or more

Useful Functions for a Wide Variety of Applications

Large Capacity Recording with SD Card

Data is recorded to a large capacity SD card. The data can be transferred to a PC and analyzed using dedicated application software. If your PC is not equipped with an SD card slot, simply connect a USB cable between the PW3198 and the PC. The PC will then recognize the SD card as removable media.

Repeat record	Recording period
OFF	Max. 35 days Reference value: ALL DATA (all items recorded), repeat recording OFF, and TIME PLOT interval 1 minute or longer)
ON	Max. 55 weeks (about 1 year) Reference value: ALL DATA (all items recorded), repeat recording ON (1 week x 55 times), and TIME PLOT interval 10 minutes or longer)

Simultaneously Measure Three-phase Lines and Grounding Wire

Apart from the main measurement line, you can also measure the AC/DC voltage on another line using Channel 4.

Yes! Simultaneously!

- Measure the primary and secondary sides of UPS
- Two-line voltage analysis
- Measure three-phase lines and grounding wire
- Measure neutral lines to detect short circuits
- Measure the input and output of a DC-AC converter for solar power generation

Remote Measurement Using HTTP Server Function

You can use any Internet browser to remotely operate the PW3198, plus download the data stored in the SD card using dedicated software (LAN access required).

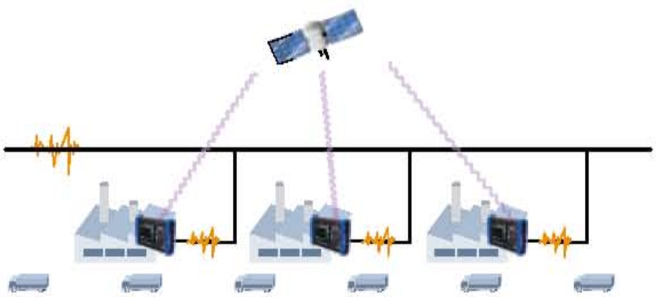
Conduct off-site remote control with a tablet PC using a wireless LAN router

An Assortment of Clamp-on Sensors Covers a Broad Range of Measurements

In addition to current sensors for measuring 100A AC, 500A AC, 1000A AC and 5000A AC rated currents, a 5A AC sensor is also available. In addition, HIOKI's CLAMP ON LEAK SENSORS enable you to accurately measure for leakage current down to the mA level, while the new CT969X-90 AC/DC Clamp On Sensors further widen applications by supporting DC current testing.

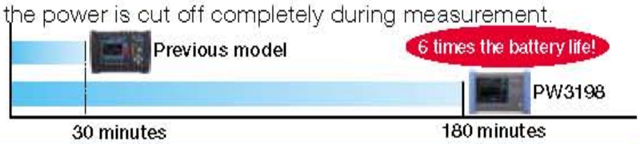
GPS Time Synchronization

The PW9005 GPS BOX lets you synchronize the clock on the PW3198 to the UTC standard time. Eliminate time differences between multiple PQAs and correctly analyze measurement data taken by several instruments.



Backup and Recovery from Power Failure

The PW3198 uses the new large capacity BATTERY PACK Z1003, enabling continuous measurement for three hours even if a power failure occurs. In addition, a power failure processing function restarts measurement automatically even if the power is cut off completely during measurement.



Other Measurement Applications

Flicker measurement

Measure flicker in conformance with IEC 61000-4-15 Ed2.

Phase voltage check for Δ connection

Use the Δ-Y and Y-Δ conversion function to measure phase voltage using a virtual neutral point.

400 Hz line measurement

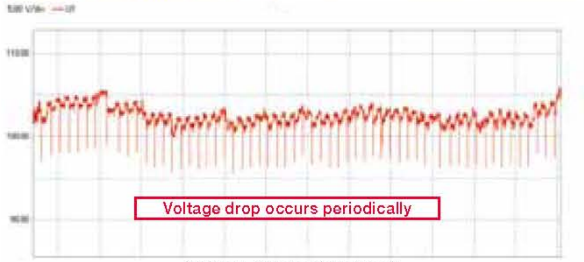
Measure at a power line frequency of 50/60 Hz as well as 400 Hz.

Power Quality Survey Applications

The power supply of the office equipment sometimes shuts down

Survey Objective
The power supply of a printer at the office shuts down even though it is not operated. Equipment other than the printer can also sometimes perform a reset unexpectedly.

Measurement Method
Setup is very easy. Just install the PW3198 on the site, and measure the voltage, current, and power. To troubleshoot, just select the clamp-on sensor and wiring, and then select the "U Events" course.



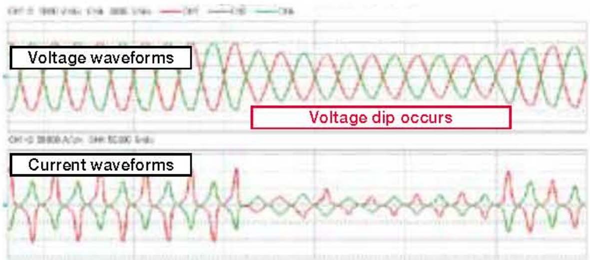
Voltage Fluctuation Graph

Analysis Report
No failure occurred during the measurement period, but a periodic voltage drop was confirmed. The voltage drop may have been caused by the periodic start and operation of the electrical equipment connected to the power supply line. **Equipment, such as a laser printer, copier, and electrical heater, may start themselves periodically due to residual heat. An instantaneous voltage drop is likely to have been caused by inrush current from equipment that consumes a large amount of power.**

Medical equipment malfunctions

Survey Objective
Replacing the equipment with a new one by the service provider did not improve the malfunction. A survey of the power supply was required to clarify the cause.

Measurement Method
Select the "U Events" course in the PW3198 in the same way as with the office equipment example.



Voltage and Current Waveforms at the Time Voltage Dip Occurs

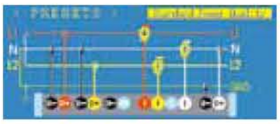
Analysis Report
It was determined that a voltage dip (voltage drop) occurred and impacted the operation of the equipment. **If a voltage dip occurs every day on a regular basis, the probable cause is the start of a large air-conditioning unit, pump, heater, or similar equipment.**

Surveying a Solar Power Generation System

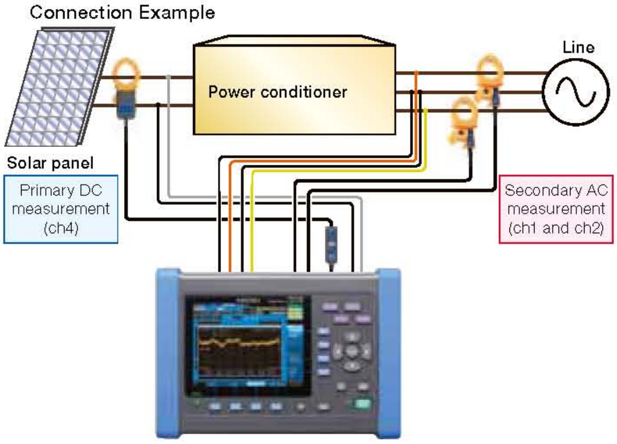
Survey Objective

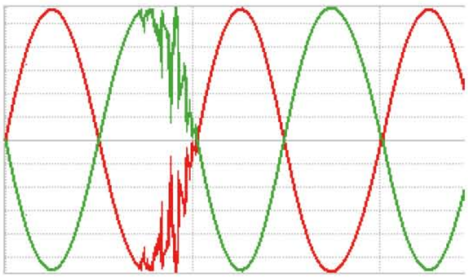
- Maintain a solar power generation system and check its operation (verify the power quality)
- Troubleshoot (impact on the peripheral equipment, operation shutdown, etc.)

Measurement Method
Set up the PW3198 on the site and measure the voltage, current, and power. To survey the power quality, select the "Standard power quality measurement" course in the PRESETS menu. To measure the DC voltage, connect channel 4 to the primary side of the solar panel.

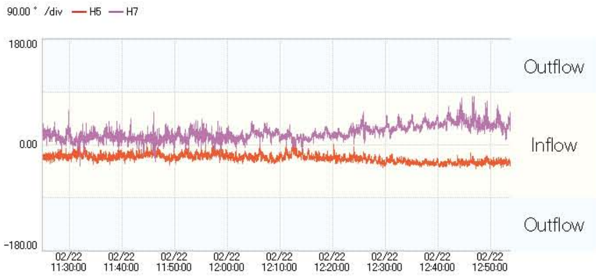


Connection Example





Example of Voltage Waveforms at the Time of Line Switching



Example of Determining Inflow or Outflow
(Inflow of 5th and 7th Order Harmonic)

Analysis Report
All parameters can be recorded simultaneously with a single measurement.

- Identify changes in the output voltage of the power conditioner
- Presence or absence of the occurrence of a transient overvoltage
- Frequency fluctuation important for system interconnection
- Identify changes in the harmonic voltage and current included in the output
- Power (AC), integral power (AC), etc.

PW3198 Specifications (Accuracy guaranteed for one year)

Measurement items

Voltage measurement items (TIME PLOT Recording)	RMS voltage Frequency DC voltage Harmonic voltage (0 to 50th order) Inter-harmonic voltage (0.5 to 49.5th) Total harmonic voltage distortion factor	Waveform voltage peak Frequency (1 cycle, 10-sec) IEC Flicker (Pst, Plt) Harmonic voltage phase angle (0 to 50th) High order harmonic voltage component Voltage Unbalance factor (Zero-phase /Negative-phase)
Current measurement items (TIME PLOT Recording)	RMS current Waveform current peak Harmonic current phase angle (0 to 50th) Harmonic current (0 to 50th) Inter-harmonic current (0.5 to 49.5th)	High order harmonic current component Total harmonic current distortion factor Current Unbalance factor (Zero-phase /Negative-phase) K factor DC current (when using compatible sensor)
Power measurement items (TIME PLOT Recording)	Active power Reactive power Apparent power Power factor	Harmonic power (0 to 50th) Harmonic voltage-current phase angle (0 to 50th) Active energy Reactive energy
EVENT measurement items (EVENT Recording)	Transient overvoltage Voltage swell Voltage dip Interruption Inrush current	Frequency fluctuations Voltage waveform comparison Timer External events
	Event detection using upper and lower thresholds available with other voltage, current and power measurement parameters (excluding Integrated power, Unbalance, Inter-harmonic, Harmonic phase angle, IEC Flicker)	

Input specifications

Measurement circuits	Single-phase 2-wire (1P2W), single-phase 3-wire (1P3W), three-phase 3-wire (3P3W2M, 3P4W2.5E) or three-phase 4-wire (3P4W) plus one extra input channel (must be synchronized to reference channel during AC/DC measurement)
Fundamental frequency of measurement circuit	50Hz, 60Hz, 400Hz
Input channels	Voltage : 4 channels (U1 to U4), Current : 4 channels (I1 to I4)
Input methods	Voltage : Isolated and differential inputs (channels not isolated between U1, U2 and U3; channels isolated between U1 to U3 and U4) Current : Insulated clamp-on sensors (voltage output)
Input resistance	Voltage : 4MΩ ±80kΩ (differential inputs) Current : 100kΩ ±10kΩ
Compatible clamp sensors	Units with f.s.=0.5V output at rated current input (f.s.=0.5V recommended) Units with rate of 0.1mV/A, 1mV/A, 10mV/A, or 100mV/A
Measurement ranges (Ch1 to Ch4 can be configured the same way; only CH4 can be configured separately)	See below

Voltage measurement ranges

Voltage measurement items	Ranges
Voltage measurement	600.00V
Transient measurement	6.0000kV peak

PW3198 current ranges

Current sensor	Current range setting (A)
9660	100.00 / 50.000
9661	500.00 / 50.000
9667 (500A) *Discontinued	500.00 / 50.000
9667 (5kA) *Discontinued	5.0000k / 500.00
CT9667 (500A)	500.00 / 50.000
CT9667 (5kA)	5.0000k / 500.00
9669	1.0000k / 100.00
9694	50.000 / 5.0000
9695-02	50.000 / 5.0000
9695-03	100.00 / 10.000

Current sensor	Current range setting(A)
CT9691 (10A)	10.000 / 5.0000
CT9691 (100A)	100.00 / 10.000
CT9692 (20A)	50.000* / 5.0000
CT9692 (200A)	500.00* / 50.000
CT9693 (200A)	500.00* / 50.000
CT9693 (2kA)	5.0000k* / 500.00
9657-10	5.0000 / 500.00m
9675	5.0000 / 500.00m

*The full scale for each sensor is based on the specifications of the sensor in use, not the range setting on the PW3198.

PW3198 Power ranges
(automatically configured based on current range)

Current range	Power range (W / VA / var)
5.0000 kA	3.0000M
1.0000 kA	600.00k
500.00 A	300.00k
100.00 A	60.000k

Current range	Power range (W / VA / var)
50.000 A	30.000k
10.000 A	6.0000k
5.0000 A	3.0000k

Basic specifications

Maximum recording period	55 weeks (with repeated recording set to [1 Week], 55 iterations) 55 days (with repeated recording set to [1 Day], 55 iterations) 35 days (with repeated recording set to [OFF])
Maximum recordable events	55,000 events (with repeated recording on) 1000 events (with repeated recording off)
TIME PLOT data settings	TIME PLOT interval (MAX/MIN/AVG within each interval recorded) 1s, 3s, 15s, 30s, 1m, 5m, 10m, 15m, 30m, 1h, 2h, 150 cycle (at 50Hz), 180 cycle (at 60Hz), 1200 cycle (at 400Hz) Screen copy interval (screen shot at each interval saved to SD card) OFF, 5m, 10m, 30m, 1h, 2h Timer EVENT interval (200ms instantaneous waveform saved at each interval) OFF, 1m, 5m, 10m, 30m, 1h, 2h Time start and End OFF: Start recording manually ON: Start time and End time can be configured Repeated recording settings (maximum 55 iterations) OFF: Recording is not repeated 1Week: 55 weeks maximum in 1week segmentations 1Day: 55 days maximum in 1day segmentations Repeat time Daily Start time and End time can be configured when Repeated recording set to 1Day.
Recording items settings	Power (Small): Recording basic parameters P&Harm (Normal): Recording basic parameters and harmonics All Data (Full): Recording P&Harm items and inter-harmonics
Memory data capacity	Max. 32 GB with SD Card; only use of the HIOKI 2GB SD Memory Card Model Z4001 is guaranteed by HIOKI. *Contact your HIOKI representative for special order larger capacity cards that offer the HIOKI guarantee.*

PRESETS function	**U Events** : Record and monitor voltage elements and frequency, plus detect events **Standard Power Quality** : Record and monitor voltage and current elements, frequency, and harmonics, plus detect events **Inrush Current** : Measure inrush current (basic voltage measurement required) **Recording** : Record only trend data, no event detection **EN50160** : Measure according to EN50160 standards
Real-Time Clock function	Auto-calendar, leap-year correcting 24-hour clock
Real-time clock accuracy	±0.3 s per day (with instrument on, 23°C±5°C (73°F±9°F)
Power supply	**AC ADAPTER Z1002** (12 VDC, Rated power supply 100VAC to 240VAC, 1.7Amax, 50/60Hz) **BATTERY PACK Z1003** (Ni-MH 7.2VDC 4500 mAh)
Maximum rated power	15VA (when not charging), 35VA (when charging)
Continuous battery operation time	Approx. 180 min. [@23°C (@73.4°F), when using **BATTERY PACK Z1003**]
Recharge function	**BATTERY PACK Z1003** charges regardless of whether the instrument is on or off; charge time: max. 5 hr. 30 min. @23°C (@73.4°F)
Power outage processing	In the event of a power outage during recording, instrument resumes recording once the power is back on (integral power starts from 0).
Power supply quality measure-ment method	IEC61000-4-30 Ed.2 :2008 IEEE1159 EN50160 (using Model **PQA-HiVIEW PRO 9624-50**)
Dimensions	Approx. 300 W× 211 H × 68 D mm (11.81" W × 8.31" H × 2.68" D) (excluding protrusions)
Mass	Approx. 2.6 kg (91.7 oz.) (including battery pack)
Accessories	Instruction manual, Measurement guide, **VOLTAGE CORD L1000** (8 cords, approx. 3 m each: 1 each red, yellow, blue, and gray plus 4 black; 8 alligator clips: 1 each red, yellow, blue, and gray plus 4 black), Spiral Tube, Input Cable Labels (for identifying channel of voltage cords and clamp-on sensors), **AC ADAPTER Z1002**, Strap, USB cable (1 m length), **BATTERY PACK Z1003**, **SD MEMORY CARD (2GB) Z4001**

Display specifications

Display	6.5-inch TFT color LCD (640 × 480 dots)

External Interface Specifications

SD card Interface	Saving of binary data, Saving and Loading setting files, Saving and Loading screen copies Slot : SD standard compliant Compatible card : SD memory card/ SDHC memory card Supported memory capacity : Max. 32 GB with SD Card; only use of the HIOKI 2GB SD Memory Card Model Z4001 is guaranteed by HIOKI. *Contact your HIOKI representative for special order larger capacity cards that offer the HIOKI guarantee.* Media full processing : Saving of data to SD memory card is stopped
RS-232C Interface	Measurement and control using GPS-synchronized time (connecting GPS BOX) Connector : D-sub9pin Connection destination : GPS box (cannot be connected to computer)
LAN Interface	1. HTTP server function (compatible software: Internet Explorer Ver.6 or later, Remote operation application function, measurement start and stop control functions, system configuration function, event list function (capable of displaying event waveforms, event vectors, and event harmonic bar graphs) 2. Downloading of data from the SD memory card using the 9624-50 PQA-HiView Pro Connector : RJ-45 Transmission method : 10BASE-T,100BASE-TX
USB2.0 Interface	1. Recognizes the SD memory card as a removable disk when connected to a computer. *The instrument cannot be connected during recording (including standby operation) or analysis.* 2. Download data from the SD memory card using the 9624-50 PQA-HiView Pro *The instrument cannot be connected during recording (including standby operation) or analysis.* Connector : Series B receptacle Connection destination : Computer [WindowsXP, WindowsVista(32bit), Windows7 (32/64bit)]
External control interface	Connector : 4-pin screwless terminal block External event input : External event input at TTL low level (at falling edge of 1.0 V or less and when shorted) between GND terminal and EVENT IN terminal Min. pulse width: 30 ms; rated voltage: -0.5 V to +6.0 V External event output : (see table below)

External event output:

External event output item setting	Operation	Pulse width
Short pulse output	TTL low output at event generation between [GND] terminal and [EVENT OUT] terminal	Low level for 10 ms or more
Long pulse output	TTL low output at event generation between [GND] terminal and [EVENT OUT] terminal (No external event output at START event)	Low level for approx. 2.5 s
ΔV10 alarm	TTL low output at ΔV10 alarm between [GND] terminal and [EVENT OUT] terminal	Low level while alarm occurring ; reverts to high at data reset

Environment and safety specifications

Operating environment	Indoors, altitude up to 3000 m (measurement category is lowered to 600 V CAT III when above 2000m), Pollution degree 2
Storage temperature and humidity	-20 to 50°C (-4 to 122°F) 80% RH or less (non-condensating) (If the instrument will not be used for an extended period of time, remove the battery pack and store in a cool location [from -20 to 30°C (-4 to 86°F)].)
Operating temperature and humidity	0 to 50°C (32 to 122°F) 80% RH or less (non-condensating)
Dust and water resistance	IP30 (EN60529)
Maximum input voltage	Voltage input section 1000 VAC, DC±600 V, max. peak voltage ±6000 Vpeak Current input section 3VAC, DC±4.24V
Maximum rated voltage to earth	Voltage input terminal 600 V (Measurement Categories IV, anticipated transient overvoltage 8000 V)
Dielectric strength	6.88 kVrms (@50/60 Hz, 1 mA sense current): Between voltage measurement terminals (U1 to U3) and voltage measurement terminals (U4) 4.30 kVrms (1 mA@50/60 Hz, 1 mA sense current): Between voltage input terminal (U1 to U3) and current input terminals/interfaces Between voltage (U4) and current measurement terminals, and interfaces
Applicable standards	Safety EN61010 EMC EN61326 Class A, EN61000-3-2, EN61000-3-3

Measurement Specifications (For specifications when measuring 400Hz circuits, please inquire with your HIOKI distributor.)

- TIME PLOT : The MAX/MIN/AVG of each recording interval for each parameter are recorded.
- EVENT : When a power anomaly occurs, approx. 200ms instantaneous waveform is recorded.
- TRANSIENT : When a transient overvoltage is detected, the 2ms instantaneous waveforms before and after the occurrence (total 4ms) are recorded.
- FLUCTUATION : The RMS fluctuation 0.5s before and 29.5s after an event has occurred are recorded.
- HIGH-ORDER HARM : When a high order harmonic event occurs, the 40ms instantaneous waveform is recorded.

Transient overvoltage — TRANSIENT, EVENT

Display items	For single transient incidents and continuous transient incidents Transient voltage value, Transient width For continuous transient incidents Transient period (Period from transient IN to transient OUT) Max. transient voltage value (Max. peak value during the period) Transient count during period
Measurement method	Detected from waveform obtained by eliminating the fundamental component (50/60/400 Hz) from the sampled waveform
Sampling frequency	2MHz
Measurement range, resolution	±6.0000kVpeak, 0.0001kV
Measurement bandwidth	5 kHz (-3dB) to 700 kHz (-3dB)
Min. detection width	0.5 μs
Measurement accuracy	±5.0% rdg.±1.0%f.s.

RMS voltage/ RMS current refreshed each half-cycle — TIME PLOT, EVENT

Measurement method	RMS voltage refreshed each half-cycle : True RMS type, RMS voltage values are calculated using sample data for 1 waveform derived by overlapping the voltage waveform every half-cycle RMS current refreshed each half-cycle : RMS current is calculated using current waveform data sampled every half-cycle
Sampling frequency	200kHz
Measurement range, resolution	RMS voltage refreshed each half-cycle : 600.00V, 0.01V RMS current refreshed each half-cycle : Based on clamp-on sensor in use; see Input specifications
Measurement accuracy	RMS voltage refreshed each half-cycle : ±0.2% of nominal voltage (With 1.666% f.s. to 110% f.s. input and a nominal input voltage of at least 100 V) ±0.2%rdg.±0.08%f.s. (With input outside the range of 1.666% f.s. to 110% f.s. or a nominal input voltage of less than 100 V) RMS current refreshed each half-cycle : ±0.3% rdg.±0.5%f.s. + clamp-on sensor accuracy

Swell/ Dip/ Interruption — FLUCTUATION, EVENT

Display item	Swell : Swell height, Swell duration Dip : Dip depth, Dip duration Interruption : Interruption depth, Interruption duration
Measurement method	Swell : A swell is detected when the RMS voltage refreshed each half-cycle exceeds the threshold in the positive direction Dip : A dip is detected when the RMS voltage refreshed each half-cycle exceeds the threshold in the negative direction Interruption : An interruption is detected when the RMS voltage refreshed each half-cycle exceeds the threshold in the negative direction
Range and accuracy	See RMS voltage refreshed each half-cycle

Inrush current — FLUCTUATION, EVENT

Display item	Maximum current of RMS current refreshed each 1/2 cycle
Measurement method	Detected when the RMS current refreshed each 1/2 cycle exceeds the threshold in a positive direction
Range and accuracy	See RMS current refreshed each half-cycle

RMS voltage, RMS current — TIME PLOT, EVENT

Display items	RMS voltage : RMS voltage for each channel and AVG (average) RMS voltage for multiple channels RMS current : RMS current for each channel and AVG (average) RMS current for multiple channels
Measurement method	AC+DC True RMS type (Current DC value: with release of new clamp-on sensor) RMS value calculated from 10 cycles (50 Hz) or 12 cycles (60 Hz)
Sampling frequency	200kHz
Measurement range, resolution	RMS voltage : 600.00V, 0.01V RMS current : Based on clamp-on sensor in use; see Input specifications
Measurement accuracy	RMS voltage : ±0.1% of nominal voltage (With 1.666% f.s. to 110% f.s. input and a nominal input voltage of at least 100 V) ±0.2%rdg.±0.08%f.s. (With input outside the range of 1.666% f.s. to 110% f.s. or a nominal input voltage of less than 100 V) RMS current : ±0.2% rdg.±0.1%f.s. + clamp-on sensor accuracy

Voltage waveform peak/ Current waveform peak — TIME PLOT, EVENT

Display item	Positive peak value and negative peak value
Measurement method	Measured every 10 cycles (50 Hz) or 12 cycles (60 Hz) maximum and minimum points sampled during approx. 200 ms aggregation
Sampling frequency	200kHz
Measurement range, resolution	Voltage waveform peak : ±1200.0 Vpeak, 0.1V Current waveform peak : The quadruple of RMS current measurement range (Based on clamp-on sensor in use; See Input specifications)

Voltage waveform comparison — EVENT

Display item	Event detection only
Measurement method	A judgment area is automatically generated from the previous 200 ms aggregation waveform, and events are generated based on a comparison with the judgment waveform. Waveform judgments are performed once for each 200 ms aggregation.
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations

Frequency cycle — TIME PLOT, EVENT

Measurement method	Calculated as the reciprocal of the accumulated whole-cycle time during one U1 (reference channel) cycle
Measurement range, resolution	70.000Hz, 0.001Hz
Measurement bandwidth	40.000 to 70.000Hz
Measurement accuracy	±0.200 Hz or less (for input from 10% f.s. to 110% f.s.)

Frequency — TIME PLOT, EVENT

Measurement method	Calculated as the reciprocal of the accumulated whole-cycle time during approx. 200ms period of 10 or 12 U1 (reference channel) cycles
Measurement range, resolution	70.000Hz, 0.001Hz
Measurement bandwidth	40.000 to 70.000Hz
Measurement accuracy	±0.020 Hz or less

10-sec frequency — TIME PLOT

Measurement method	Calculated as the reciprocal of the accumulated whole-cycle time during the specified 10s period for U1 (reference channel) as per IEC61000-4-30
Measurement range, resolution	70.000Hz, 0.001Hz
Measurement bandwidth	40.000 to 70.000Hz
Measurement accuracy	±0.010 Hz or less

Voltage DC value (ch4 only)

TIME PLOT EVENT

Measurement method	Average value during approx. 20ms aggregation synchronized with the reference channel (CH4 only)
Sampling frequency	200kHz
Measurement range, resolution	600.00V, 0.01V
Measurement accuracy	±0.3%rdg. ±0.08%f.s.

Current DC value (ch4 only; when using compatible sensor)

TIME PLOT EVENT

Measurement method	Average value during approx. 200ms aggregation synchronized to reference channel (CH4 only)
Sampling frequency	200kHz
Measurement range, resolution	Based on clamp-on sensor in use (with release of new clamp-on sensor)
Measurement accuracy	±0.5% rdg.±0.5%f.s. + clamp-on sensor accuracy

Active power/ Apparent power/ Reactive power

TIME PLOT EVENT

Display items	Active power : Active power for each channel and sum value for multiple channels. Sink (consumption) and Source (regeneration) Apparent power : Apparent power of each channel and its sum for multiple channels No polarity Reactive power : Reactive power of each channel and its sum for multiple channels Lag phase (LAG: current lags voltage) and Lead phase (LEAD: current leads voltage)
Measurement method	Active power : Measured every 10 cycles (50 Hz) or 12 cycles (60 Hz) Apparent power : Calculated from RMS voltage U and RMS current I Reactive power : Calculated using apparent power S and active power P
Sampling frequency	200kHz
Measurement range, resolution	Depends on the voltage × current range combination; see Input specifications
Measurement accuracy	Active power : ±0.2% rdg.±0.1%f.s. + clamp-on sensor accuracy Apparent power : ±1 dgt. for calculations derived from the various measurement values Reactive power : ±1 dgt. for calculations derived from the various measurement values

Active energy /Reactive energy

TIME PLOT

Display items	Active energy : WP+ (consumption), WP- (regeneration); Sum of multiple channels Reactive energy : WQLAG (lag), WQLEAD (lead); Sum for multiple channels Elapsed time
Measurement method	Measured every 10 cycles (50 Hz) or 12 cycles (60 Hz) Integrated separately by consumption and regeneration from active power Integrated separately by lag and lead from reactive power Integration starts at the same time as recording Recorded at the specified TIMEPLOT interval
Sampling frequency	200kHz
Measurement range, resolution	Depends on the voltage × current range combination; see Input specifications
Measurement accuracy	Active energy : Active power measurement accuracy ±10 dgt. Reactive energy : Reactive power measurement accuracy ±10 dgt.

Power factor /Displacement power factor

TIME PLOT EVENT

Display items	Displacement power factor of each channel and its sum value for multiple channels
Measurement method	Power factor : Calculated from RMS voltage U, RMS current I, and active power P Displacement power factor : Calculated from the phase difference between the fundamental voltage wave and the fundamental current wave Lag phase (LAG: current lags voltage) and Lead phase (LEAD: current leads voltage
Sampling frequency	200kHz
Measurement range, resolution	-1.0000 (lead) to 0.0000 to 1.0000 (lag)

Voltage unbalance factor/ Current unbalance factor (negative-phase, zero-phase)

TIME PLOT

Display items	Voltage unbalance factor : Negative-phase unbalance factor, zero-phase unbalance factor Current unbalance factor : Negative-phase unbalance factor, zero-phase unbalance factor
Measurement method	Calculated using various components of the three-phase fundamental wave (line-to-line voltage) for three-phase 3-wire (3P3W2M, 3P3W3M) and three-phase 4-wire connections
Sampling frequency	200kHz
Measurement range	Voltage unbalance factor : Component is V and unbalance factor is 0.00% to 100.00% Current unbalance factor : Component is V and unbalance factor is 0.00% to 100.00%
Measurement accuracy	Voltage unbalance factor : ±0.15% Current unbalance factor : —

High-order harmonic voltage component/ High-order harmonic current component

HIGH-ORDER HARM TIME PLOT EVENT

Display items	For single incidents and continuous transient incidents High-order harmonic voltage component value High-order harmonic current component value For continuous incidents High-order harmonic voltage component maximum value High-order harmonic current component maximum value High-order harmonic voltage component period High-order harmonic current component period
Measurement method	The waveform obtained by eliminating the fundamental component is calculated using the true RMS method during 10 cycles (50 Hz) or 12 cycles (60 Hz) of the fundamental wave
Sampling frequency	200kHz
Measurement range, resolution	High-order harmonic voltage component : 600.00V, 0.01V High-order harmonic current component : Based on clamp-on sensor in use; See Input specifications
Measurement bandwidth	2kHz (-3dB) to 80kHz (-3dB)
Measurement accuracy	High-order harmonic voltage component : ±10%rdg. ±0.1%f.s. High-order harmonic current component : ±10% rdg.±0.2%f.s. + clamp-on sensor accuracy

Harmonic voltage/ Harmonic current (including fundamental component)

TIME PLOT EVENT

Display items	Select either RMS or content percentage; From 0 to 50th order
Measurement method	Uses IEC61000-4-7:2002.
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	Harmonic voltage : 600.00V, 0.01V Harmonic current : Based on clamp-on sensor in use; see Input specifications
Measurement accuracy	See measurement accuracy with a fundamental wave of 50/60 Hz When using an AC-only clamp sensor, 0th order is not specified for current and power

Total harmonic voltage/ Total harmonic current distortion factor

TIME PLOT EVENT

Display items	THD-F (total harmonic distortion factor for the fundamental wave) THD-R (total harmonic distortion factor for the total harmonic including the fundamental wave)
Measurement method	Based on IEC61000-4-7:2002; Max. order: 50th
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	0.00 to 100.00%(Voltage), 0.00 to 500.00%(Current)
Measurement accuracy	—

Harmonic power (including fundamental component)

TIME PLOT EVENT

Display item	Select either RMS or content percentage; From 0 to 50th order
Measurement method	Uses IEC61000-4-7:2002.
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	Depends on the voltage × current range combination; See Input specifications
Measurement accuracy	See measurement accuracy with a fundamental wave of 50/60 Hz (When using an AC-only clamp sensor, order 0 is not specified for current and power)

Measurement accuracy with a fundamental wave of 50/60 Hz

Harmonic input	Measurement accuracy
Voltage (At least 1% of nominal voltage)	Specified with a nominal voltage of at least 100 V Order 0: ±0.3%rdg.±0.08%f.s. Order 1+: ±5.00%rdg
Voltage (<1% of nominal voltage)	Specified with a nominal voltage of at least 100 V Order 0: ±0.3%rdg.±0.08%f.s. Order 1+: ±0.05% of nominal voltage
Current	Order 0: ±0.5%rdg.±0.5%f.s. +clamp-on sensor accuracy Order 1 to 20th: ±0.5%rdg.±0.2%f.s. +clamp-on sensor accuracy Order 21 to 50th: ±1.0%rdg.±0.3%f.s. +clamp-on sensor accuracy
Power	Order 0: ±0.5%rdg.±0.5%f.s. +clamp-on sensor accuracy Order 1 to 20th: ±0.5%rdg.±0.2%f.s. +clamp-on sensor accuracy Order 21 to 30th: ±1.0%rdg.±0.3%f.s. +clamp-on sensor accuracy Order 31 to 40th: ±2.0%rdg.±0.3%f.s. +clamp-on sensor accuracy Order 41 to 50th: ±3.0%rdg.±0.3%f.s. +clamp-on sensor accuracy

Harmonic voltage phase angle/ Harmonic current phase angle (including fundamental component)

TIME PLOT

Display item	Harmonic phase angle components for whole orders
Measurement method	Uses IEC61000-4-7:2002.
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	-180.00° to 0.00° to 180.00°
Measurement accuracy	—

Harmonic voltage-current phase angle (including fundamental component)

TIME PLOT EVENT

Display item	Indicates the difference between the harmonic voltage phase angle and the harmonic current phase angle. Harmonic voltage-current phase difference for each channel and sum (total) value for multiple channels
Measurement method	Uses IEC61000-4-7:2002.
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	-180.00° to 0.00° to 180.00°
Measurement accuracy	1st to 3rd orders : ± 2° +clamp-on sensor accuracy 4th to 50th orders: ±(0.05° × k+2°) +clamp-on sensor accuracy; (k: harmonic orders) Specified with a harmonic voltage of 1 V for each order and a current level of at 1% f.s. or greater.

Inter-harmonic voltage and inter-harmonic current

TIME PLOT

Display item	Select either RMS or content percentage; 0.5 to 49.5th orders
Measurement method	Uses IEC61000-4-7:2002.
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	Inter-harmonic voltage : 600.00V, 0.01V Inter-harmonic current : Due to using clamp-on sensor; See Input specifications
Measurement accuracy	Inter-harmonic voltage (Specified with a nominal voltage of at least 100 V) : At least 1% of harmonic input nominal voltage : ±5.00% rdg. <1% of harmonic input nominal voltage : ±0.05% of nominal voltage Inter-harmonic current : Unspecified

K Factor (multiplication factor)

TIME PLOT EVENT

Measurement method	Calculated using the harmonic RMS current of the 2nd to 50th orders
Comparison window width	10 cycles (50 Hz), 12 cycles (60 Hz)
No. of window points	4096 points synchronized with harmonic calculations
Measurement range, resolution	0.00 to 500.00
Measurement accuracy	—

Instantaneous flicker value

TIME PLOT

Measurement method	As per IEC61000-4-15 User-selectable from 230 Vlamp/120 Vlamp (when Pst and Plt are selected for flicker measurement)/4 types of Ed2 filter (230 Vlamp 50/60 Hz, 120 Vlamp 60/50 Hz)
Measurement range, resolution	99.999, 0.001

ΔV10 Flicker

TIME PLOT

Display items	ΔV10 measured at one minute intervals, average value for one hour, maximum value for one hour, fourth largest value for one hour, total (within the measurement interval) maximum value
Measurement method	Calculated values are subject to 100 V conversion following gap-less measurement once each minute
Measurement range, resolution	0.000 to 99.999V
Measurement accuracy	±2% rdg.±0.01 V (with a fundamental wave of 100 Vrms [50/60 Hz], a fluctuation voltage of 1 Vrms, and a fluctuation frequency of 10 Hz)
Threshold	0.00 to 9.99V alarm output is generated when the reading for each minute is compared to the threshold and found to be greater

IEC Flicker

TIME PLOT

Display items	Short interval flicker Pst, long interval flicker Plt
Measurement method	Based on IEC61000-4-15:1997 +A1:2003 Ed1/Ed2. Pst is calculated after 10 minutes of continuous measurement and Plt after 2 hours of continuous measurement
Measurement range	0.0001 to 10000 P.U. broken into 1,024 segments with a logarithm
Measurement accuracy	Pst ±5% rdg. (Specified within range 0.1000 to 20.000 using IEC61000-4-15 Ed1.1 and IEC61000-4-15 Ed2 Class F1 performance test.)
Flicker filter	Select 230 V lamp Ed1, 120 V lamp Ed1, 230 V lamp Ed2, or 120 V lamp Ed2.

Clamp-on sensors specifications (Options)

Clamp-on sensor	CLAMP ON SENSOR 9694	CLAMP ON SENSOR 9660	CLAMP ON SENSOR 9661
Appearance			
Primary current rating	5A AC	100A AC	500A AC
Output voltage	10mV/A AC	AC 1mV/A AC	AC 1mV/A AC
Measurement range	See input specifications		
Amplitude accuracy *	±0.3%rdg.±0.02%f.s. *	±0.3%rdg.±0.02%f.s. *	±0.3%rdg.±0.01%f.s *
Phase accuracy *	±2° or less *	±1° or less *	±0.5° or less *
Maximum allowable input *	50 A continuous *	130 A continuous *	550 A continuous *
Maximum rated voltage to earth	CAT III 300Vrms		CAT III 600 Vrms
Frequency characteristics	±1.0% or less for 66Hz to 5kHz (deviation from specified accuracy)		
Cord length	3m (9.84ft)		
Measurable conductor diameter	Max.φ15mm (0.59")		Max.φ46mm (1.81")
Dimensions, Mass	46W(1.81")x135H(5.31")x21D(0.83")mm, 230g(8.1oz.)		78W(3.07")x152H(5.98")x42D(1.65")mm, 380g(13.4oz.)

*: 45 to 66Hz

Clamp-on sensor	CLAMP ON SENSOR 9669	FLEXIBLE CLAMP ON SENSOR CT9667
Appearance		
Primary current rating	1000 A AC	500A AC, 5000A AC
Output voltage	0.5mV/A AC	500 mV AC f.s.
Measurement range	See input specifications	
Amplitude accuracy *	±1.0%rdg.±0.01%f.s. *	±2.0%rdg.±0.3%f.s. *
Phase accuracy *	±1° or less *	±1° or less *
Maximum allowable input *	1000 A continuous *	10000 A continuous *
Maximum rated voltage to earth	CAT III 600Vrms	CATIII 1000 Vrms CATIV 600 Vrms
Frequency characteristics	Within ±2% at 40Hz to 5kHz (deviation from accuracy)	±3dB or less for 10 Hz to 20kHz (within ±3dB)
Cord length	3m (9.84ft)	Sensor to circuit: 2m (6.56ft) Circuit to connector: 1m (3.28ft)
Measurable conductor diameter	Max. φ55 mm(2.17"), 80 (3.15")x20(0.79") mm busbar	Max. φ254mm(10")
Dimensions, Mass	99.5W (3.92") x 188H (7.40") x 42D (1.65") mm, 590g (20.8 oz.)	Circuit box: 35W (1.38") x 120.5H (4.74") x 34D (1.34") mm, 140 g (4.9 oz.)
Power supply	—	LR6 alkaline battery x2, AC Adapter (option) or external 5 to 15 V DC power supply
Options (sold separately)		AC ADAPTER 9445-02 (universal 100 to 240VAC, 9V1A output for USA) AC ADAPTER 9445-03 (universal 100 to 240VAC, 9V1A output for Europe)

*: 45 to 66Hz

Clamp-on sensor	CLAMP ON SENSOR 9695-02	CLAMP ON SENSOR 9695-03
Appearance		
Primary current rating	50A AC	100A AC
Output voltage	10mV/A AC	1mV/A AC
Measurement range	See input specifications	
Amplitude accuracy *	±0.3%rdg.±0.02%f.s. *	±0.3%rdg.±0.02%f.s. *
Phase accuracy *	Within ±2° *	Within ±1° *
Maximum allowable input *	130 A continuous *	130 A continuous *
Maximum rated voltage to earth	CAT III 300Vrms (insulated conductor)	
Frequency characteristic	Within ±2% at 40Hz to 5kHz (deviation from accuracy)	
Cord length	CONNECTION CORD 9219 (sold separately) is required.	
Measurable conductor diameter	Max. φ15mm (0.59")	
Dimensions, Mass	51W(2.01")x58H(2.28")x19D(0.75")mm, 50g(1.8oz.)	
Options (sold separately)	CONNECTION CORD 9219 (Cord length:3m (9.84ft))	

Note: CONNECTION CORD 9219 (sold separately) is required.
*: 45 to 66Hz


CONNECTION CORD 9219

Clamp-on AC/DC sensor	AC/DC CLAMP ON SENSOR CT9691-90 (CT9691 bundled with the CT6590)	AC/DC CLAMP ON SENSOR CT9692-90 (CT9692 bundled with the CT6590)	AC/DC CLAMP ON SENSOR CT9693-90 (CT9693 bundled with the CT6590)
Appearance			
Includes	CT9691 ×1, CT6590 ×1	CT9692 ×1, CT6590 ×1	CT9693 ×1, CT6590 ×1

CT9691,CT9692,CT9693 (Clamp sensor) specifications

	CT9691	CT9692	CT9693
Primary current rating	100A AC/DC	200A AC/DC	2000A AC/DC
Maximum input range (RMS value)	100Arms continuous*	200Arms continuous*	2000Arms continuous*
Maximum rated voltage to earth	CAT III AC/DC 600V		
Frequency band	DC to 10 kHz (-3dB)	DC to 20 kHz (-3dB)	DC to 15 kHz (-3dB)
Cord length	2m (6.5 ft)		
Measurable conductor diameter	35 mm (1.38") or less	33 mm (1.30") or less	55 mm (2.17") or less
Dimensions, Mass	53W(2.09") × 129H(5.08") × 18D(0.71") mm, 230g (8.1 oz.)	62W(2.44") × 167H(6.57") × 35D(1.38") mm, 410g (14.5 oz.)	62W(2.44") × 196H(7.72") × 35D(1.38") mm, 500g (17.6 oz.)

CT6590 (SENSOR UNIT) specifications

	CT6590		
Range when combined with sensor (H/L selectable)	H range : 100A AC/DC f.s. L range : 10A AC/DC f.s.	H range : 200A AC/DC f.s. L range : 20A AC/DC f.s.	H range : 2000A AC/DC f.s. L range : 200A AC/DC f.s.
Sensor combination Output rate	H range : 1mV/A L range : 10mV/A	H range : 1mV/A L range : 10mV/A	H range : 0.1mV/A L range : 1mV/A
Sensor combination measurement range	See input specifications		
Sensor combination accuracy (Continuous input)	±1.5%rdg.±1.0%f.s. (DC ≤ f ≤ 66 Hz)	±1.5%rdg.±0.5%f.s. (DC ≤ f ≤ 66 Hz)	±2.0%rdg.±0.5%f.s. (DC) ±1.5%rdg.±0.5%f.s. (45 ≤ f ≤ 66Hz, I ≤ 1800A) ±2.5%rdg.±0.5%f.s. (45 ≤ f ≤ 66Hz, 1800A<I ≤ 2000A)
Sensor combination accuracy (Phase)	±2deg. (DC < f ≤ 66 Hz)	±2deg. (DC < f ≤ 66 Hz)	±2deg. (45Hz ≤ f ≤ 66 Hz)
Cord length	1m (3.3ft)		
Dimensions, Mass	36W(1.42") × 120H(4.72") × 34D(1.34") mm (excluding protruding parts), 165g(5.8 oz.) (including batteries)		
Power supply	LR6 alkaline battery x2, optional AC adapter, or 5 V to 15 VDC external power		
Options (sold separately)	AC ADAPTER 9445-02 (universal 100 to 240VAC , 9V/1A output/for USA) AC ADAPTER 9445-03 (universal 100 to 240VAC , 9V/1A output/for Europe)		

* : Derating according to frequency

Clamp-on leak sensor	CLAMP ON LEAK SENSOR 9657-10	CLAMP ON LEAK SENSOR 9675
Appearance		
Primary current rating	10A AC (Up to 5A on Model PW3198)	
Output voltage	100 mV/A AC	
Measurement range	See input specifications (Cannot be used to measure power)	
Amplitude accuracy *	±1.0%rdg.±0.05%f.s. *	±1.0%rdg.±0.005%f.s. *
Residual current characteristics	Max. 5mA (in 100A go and return electric wire)	Max. 1mA (in 10A go and return electric wire)
Effect of external magnetic fields	400A AC/m corresponds to 5mA, Max. 7.5mA	
Maximum rated voltage to earth	CATIII 300Vrms (insulated conductor)	
Cord length	3m (9.84ft)	
Measurable conductor diameter	Max. φ40 mm (1.57")	Max. φ30 mm (1.18oz")
Dimensions, Mass	74W(2.91")×145H(5.71")×42D(1.65)mm, 380g(13.4oz.)	60W(2.36")×112.5H(4.43")×23.5D(23.5")mm, 160g(5.6oz.)

* : 45 to 66Hz

Options

Current measurement (see P.14 -15 Clamp-on sensors specifications for details)

CLAMP ON SENSOR (Load current, AC)


9694
5A AC, φ15mm(0.59")


9661
500A AC, φ46mm(1.81")


CT9667
500A AC/ 5000A AC (selectable),
φ254mm (10"),
Power supply: LR06 alkaline battery
or AC ADAPTER 9445-02/03 (sold separately)


9660
100A AC, φ15mm(0.59")


9669
1000A AC, φ55mm(2.17"),
80(3.15")x20(0.79")mm busbar


9695-02 (50A AC)
9695-03 (100A AC)
φ15mm (0.59"), CONNECTION CORD 9219 is required (sold separately)


CONNECTION CORD 9219
For connecting 9695-02,9695-03
Cord length : 3m (9.84ft)

CLAMP ON AC/DC SENSOR (Load current, AC/DC)


CT9691-90
100A AC/DC / 10A AC/DC (selectable),
φ35mm(1.38")
Power supply:
LR6 alkaline battery
or AC ADAPTER 9445-02/03
(sold separately)


CT9692-90
200A AC/DC / 20A AC/DC (selectable),
φ33mm(1.30")
Power supply:
LR6 alkaline battery
or AC ADAPTER 9445-02/03
(sold separately)


CT9693-90
2000A AC/DC / 200A AC/DC (selectable),
φ55mm(2.17")
Power supply:
LR6 alkaline battery
or AC ADAPTER 9445-02/03
(sold separately)

The CT9691-90, CT9692-90, and CT9693-90 represent the respective clamp sensor bundled with the CT6590 Sensor Unit.

CLAMP ON ADAPTER


9290-10
CT ratio 10:1 , AC1000A,
φ55mm(2.17"),
80(3.15")x20(0.79")mm busbar,
Cord length : 3m(9.84ft)

CLAMP ON LEAK SENSOR (Leak Current)

Cannot be used to measure power

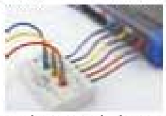

9657-10
10A AC (Up to 5A on Model PW3198),
φ40mm(1.57"),


9675
10A AC(Up to 5A on Model PW3198),
φ30mm(1.18"),

Voltage measurement


WIRING ADAPTER
PW9000
For 3P3W WIRING


WIRING ADAPTER
PW9001
For 3P4W WIRING

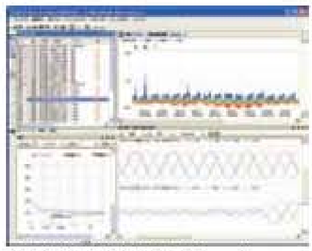

Reduce voltage cords for easy wiring

MAGNETIC ADAPTER 9804-01 (red)
MAGNETIC ADAPTER 9804-02 (black)
Magnetic tip for use with the standard Voltage Cord L1000
(generally compatible with M6 pan screws)

Red and black adapters sold separately.
Purchase the quantity and color appropriate for your application.
(Example: 3P3W - 3 adapters; 3P4W - 4 adapters)


GRABBER CLIP
9243
For use with the standard Voltage Cord L1000

Application software


PQA-HiVIEW PRO 9624-50
Use Model 9624-50 PQA-HiVIEW PRO (version 2.00 or later) with a PC to analyze the data collected by the PW3198.

Case


CARRYING CASE
C1001
Soft case
450W x 345H x 210D mm
(17.7"W x 13.6"H x 8.3"D)
3.4kg (120oz.)


CARRYING CASE
C1002
Hard case
413W x 595H x 265D mm
(16.3"W x 23.4"H x 10.4"D)
5.7kg (201oz.)

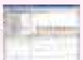
Clock synchronization


GPS BOX PW9005
To synchronize the PW3198 clock,
Accessory: Connection cable set


POWER QUALITY ANALYZER PW3198
(Bundled accessories)
SD MEMORY CARD 2GB Z4001,
VOLTAGE CORD L1000, AC ADAPTER Z1002,
BATTERY PACK Z1003 , Instruction manual,
Measurement guide, Strap, USB cable (Approx. 1m in length)

POWER QUALITY ANALYZER PW3198-90

(Set with PQA HiVIEW PRO 9624-50 and bundled accessories)



IMPORTANT

Use Model PQA-HiVIEW PRO 9624-50 (version 2.00 or later) with a PC to analyze the data collected by the PW3198.

Bundled accessories


Voltage Cord L1000
8 cords, approx. 3 m each:
1 each red, yellow, blue, and gray plus 4 black;
8 alligator clips: 1 each red, yellow, blue, and gray plus 4 black


AC ADAPTER Z1002
Power supply for the PW3198
100V AC to 240V AC


SD MEMORY CARD 2GB
Z4001

IMPORTANT

Use only the SD Card Z4001 sold by HIOKI.


BATTERY PACK Z1003
(Ni-MH, 7.2 V/4500 mAh)

●Combination example: For three-phase 4-wire circuits containing leak current

PW3198-90	+	9661 × 3	+	9675	+	PW9001	+	C1001
POWER QUALITY ANALYZER PW3198 set with PQA HiVIEW PRO 9624-50		CLAMP ON SENSOR (500A)		CLAMP ON LEAK SENSOR		WIRING ADAPTER		CARRYING CASE

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APPENDIX B. PQ LOGGING DATA (2018/2019 FY)

Please refer to the following pages.

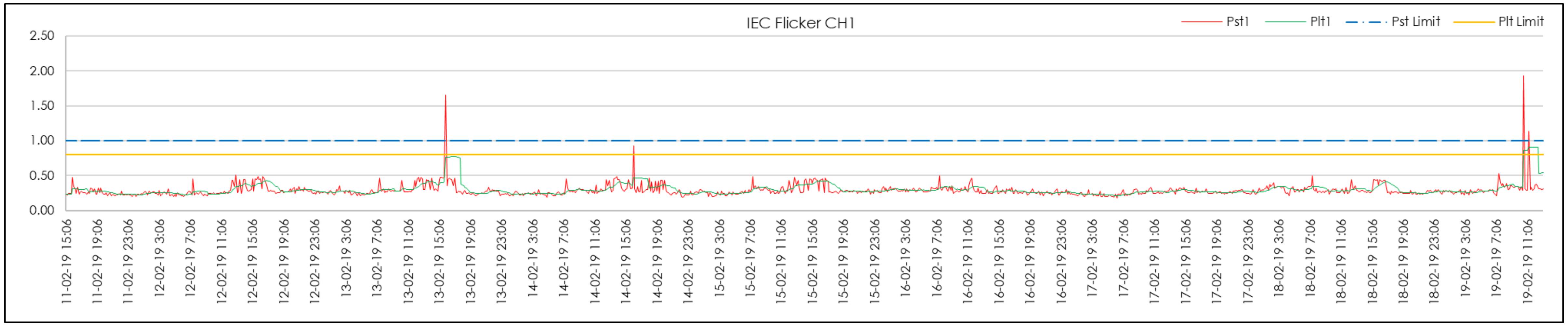

Figure 23 | TC1 Start Flicker measurements (Red Phase)

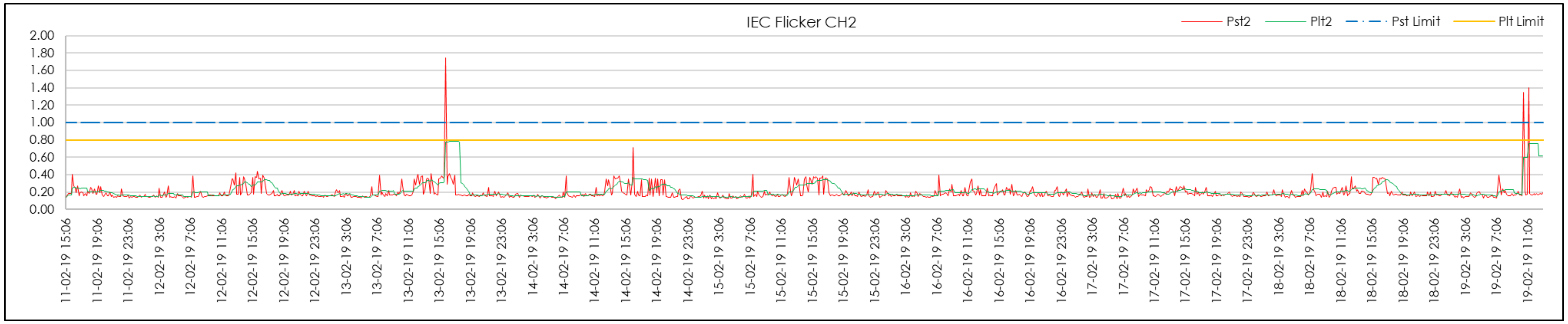

Figure 24 | TC1 Start Flicker measurements (White Phase)

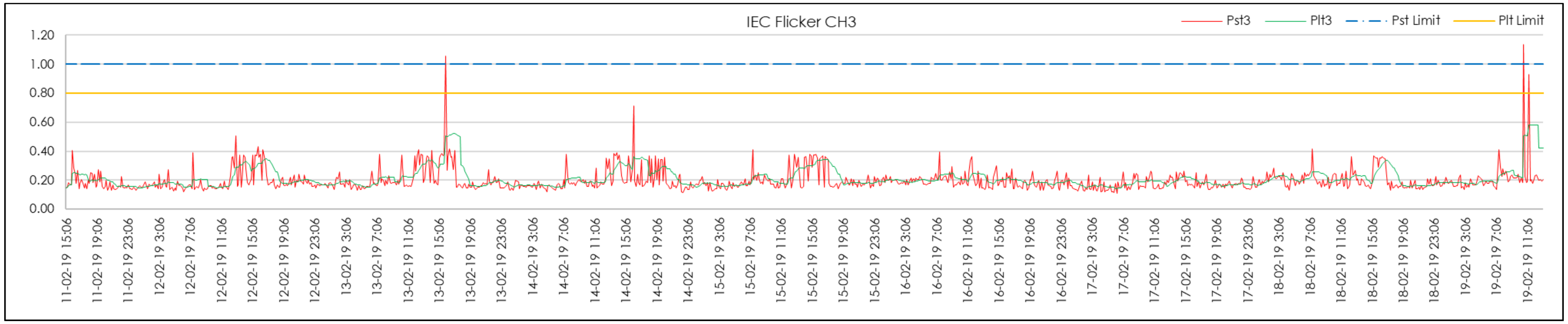

Figure 25 | TC1 Start Flicker measurements (Blue Phase)

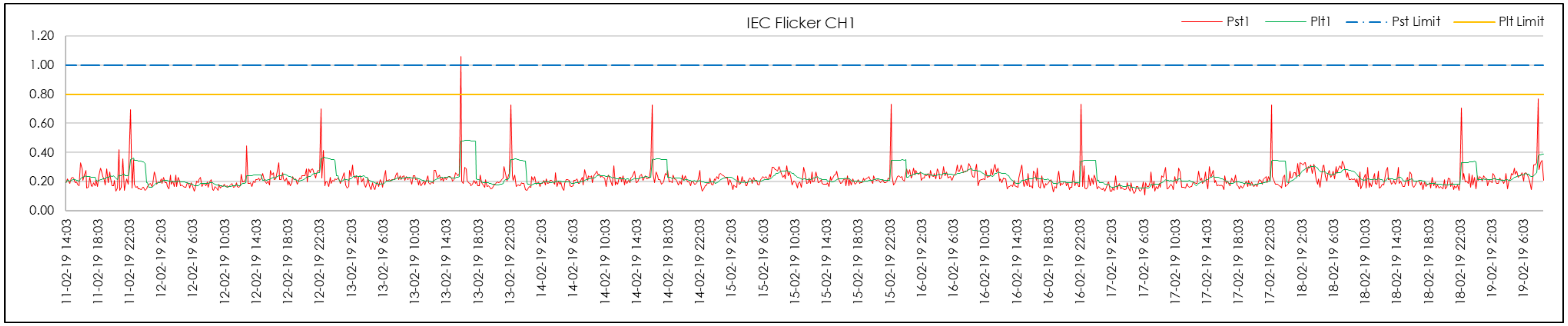

Figure 26 | TC1 End Flicker measurements (Red Phase)

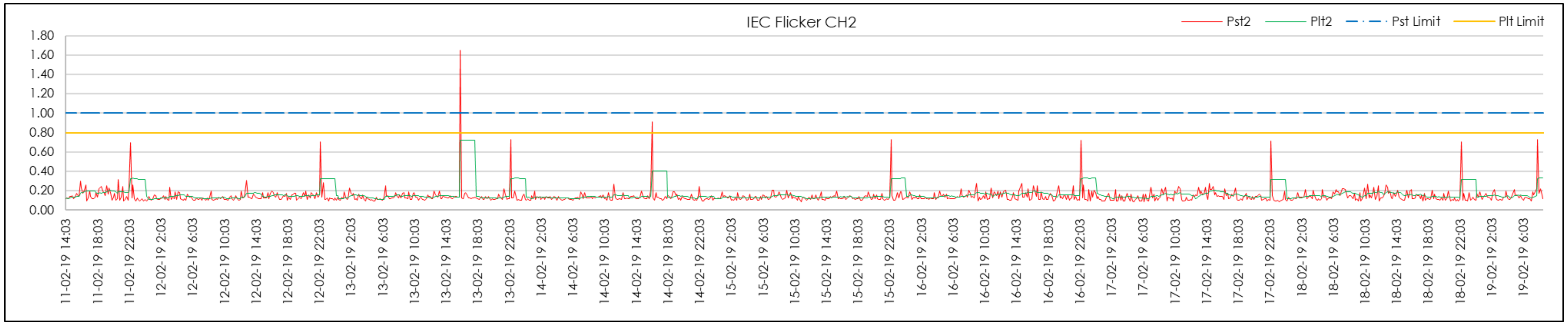

Figure 27 | TC1 End Flicker measurements (White Phase)

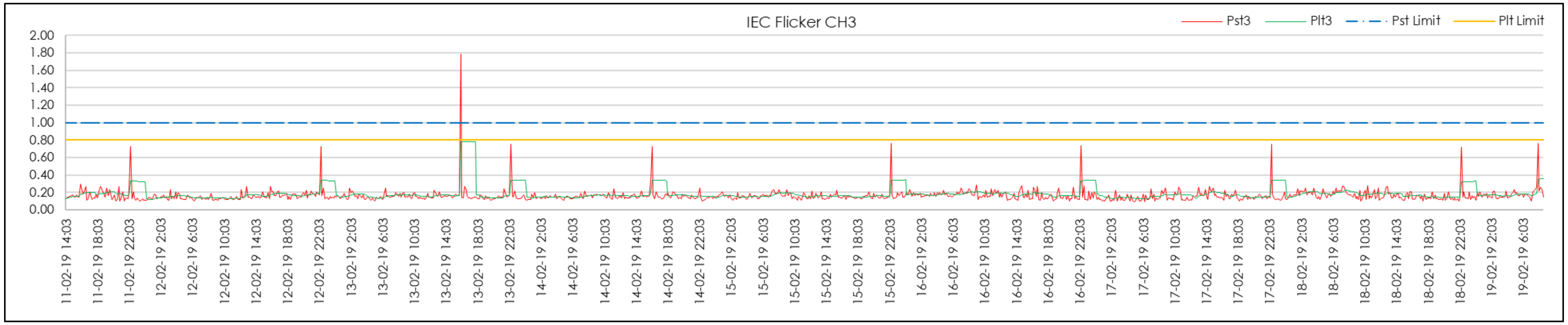

Figure 28 | TC1 End Flicker measurements (Blue Phase)

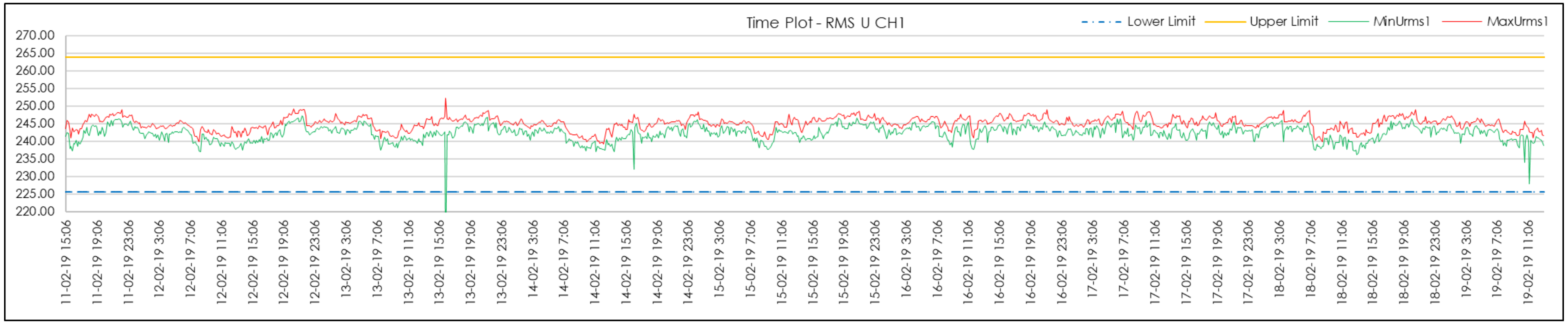

Figure 29 | TC1 Start Voltage measurements (Red Phase)

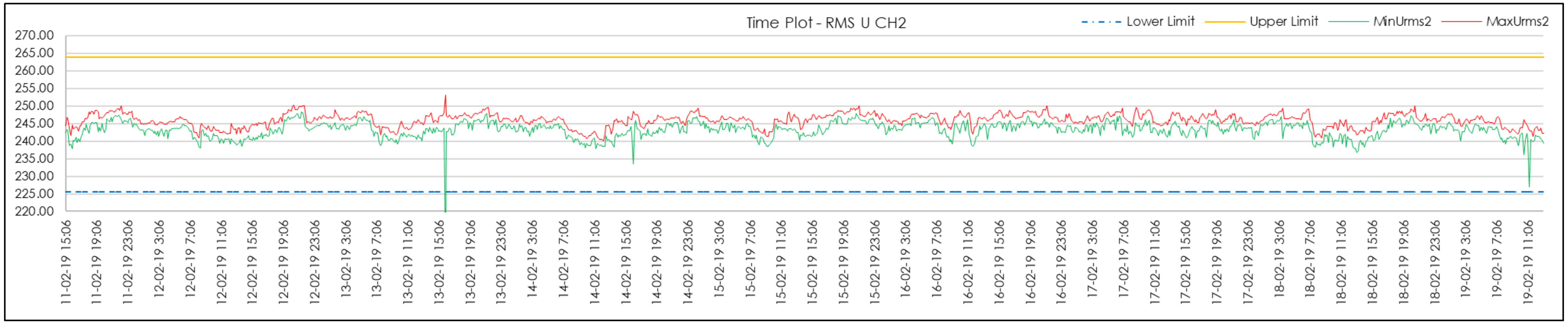

Figure 30 | TC1 Start Voltage measurements (White Phase)

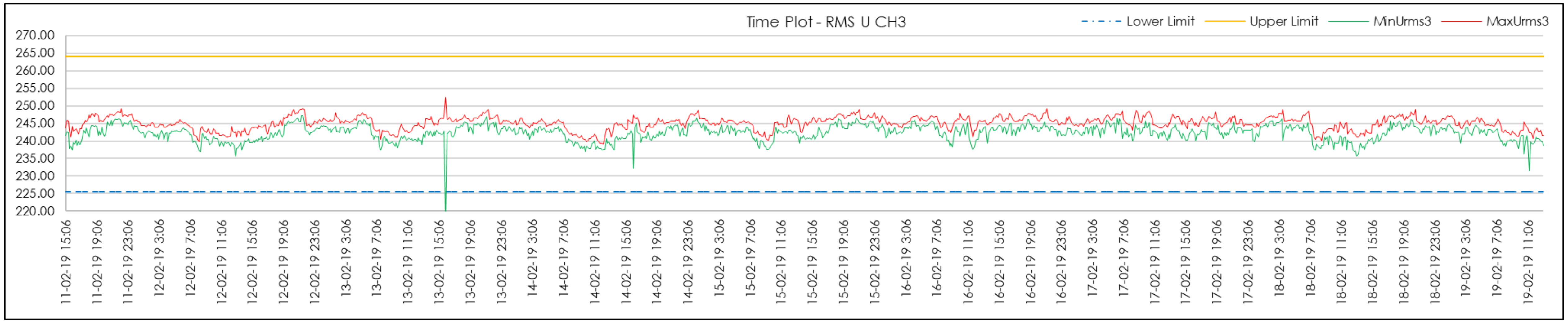

Figure 31 | TC1 Start Voltage measurements (Blue Phase)

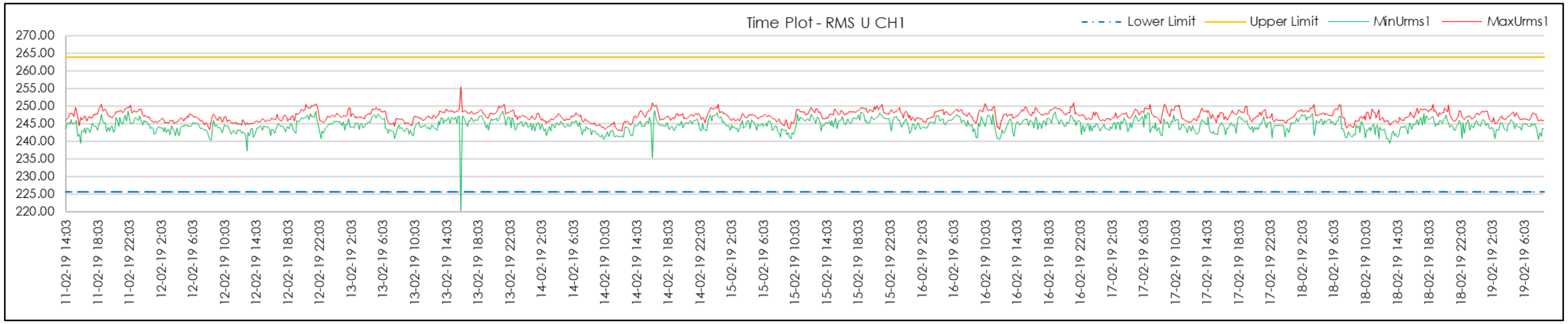

Figure 32 | TC1 End Voltage measurements (Red Phase)

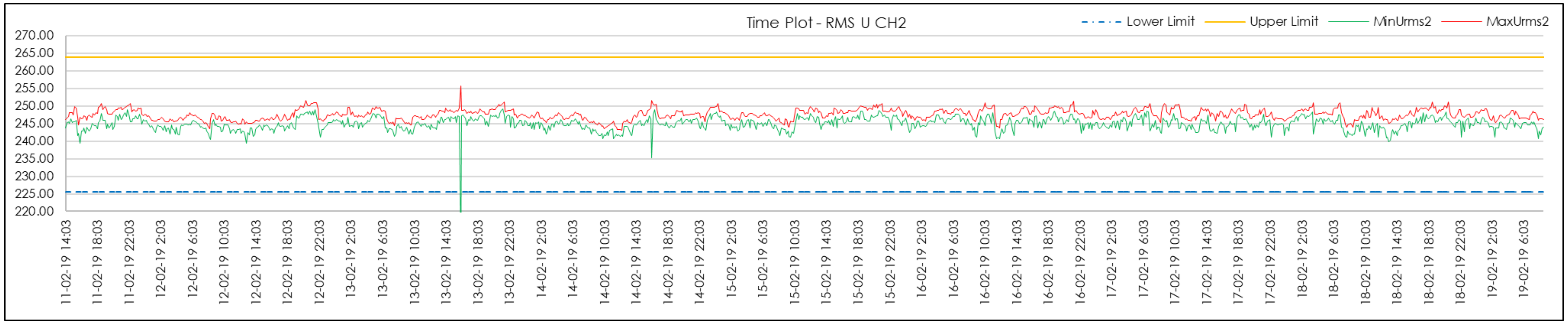

Figure 33 | TC1 End Voltage measurements (White Phase)

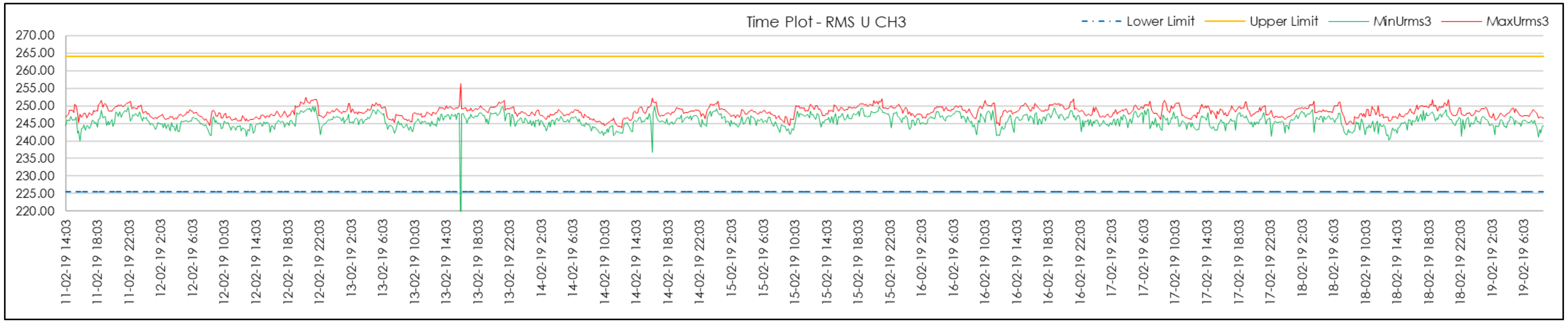

Figure 34 | TC1 End Voltage measurements (Blue Phase)

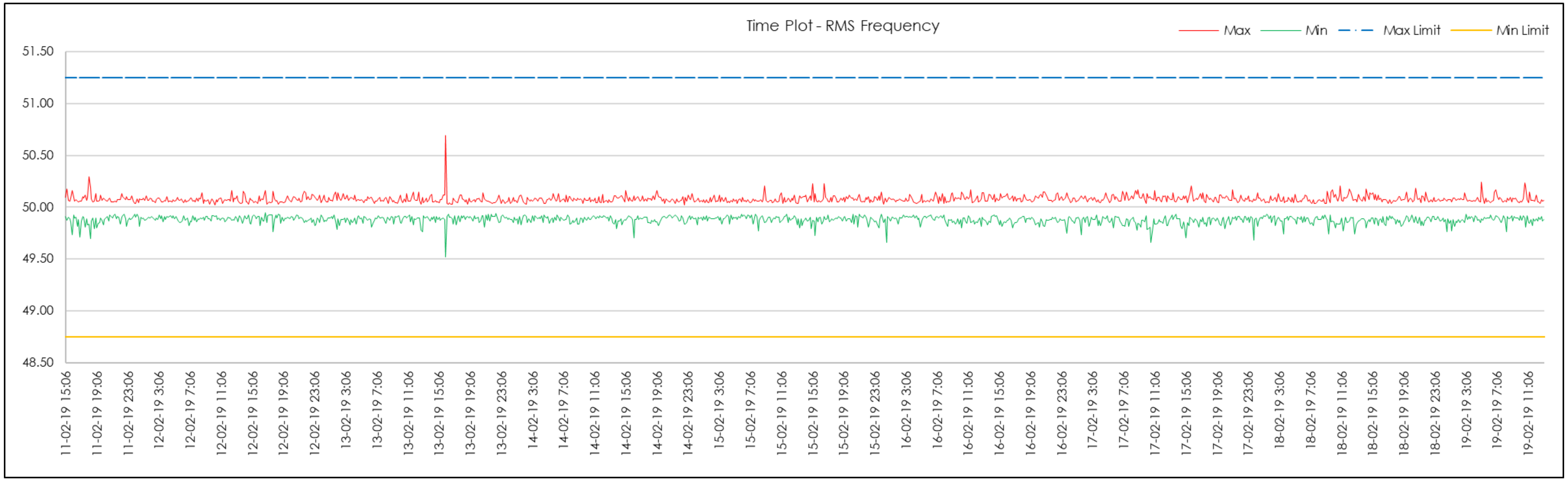

Figure 35 | TC1 Start Frequency measurements

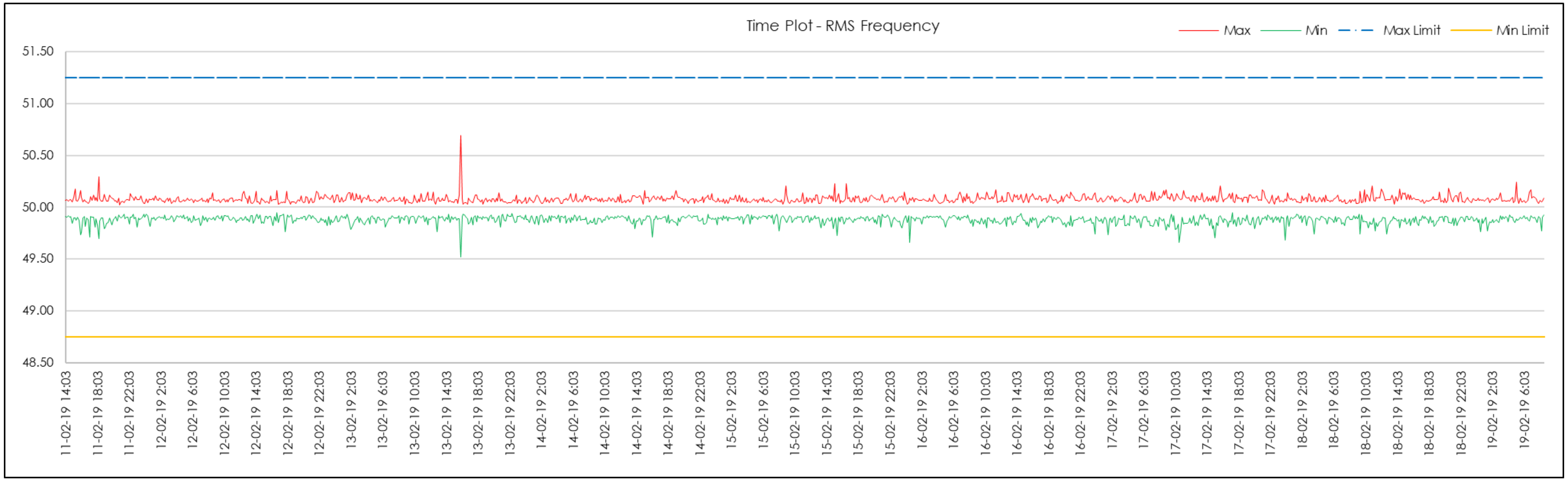

Figure 36 | TC1 End Frequency measurements

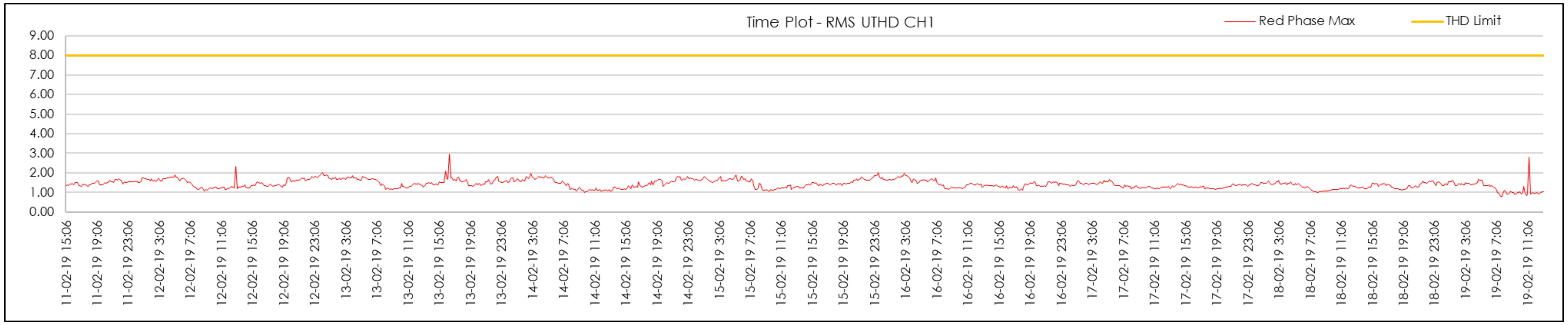

Figure 37 | TC1 Start U-THD measurements (Red Phase)

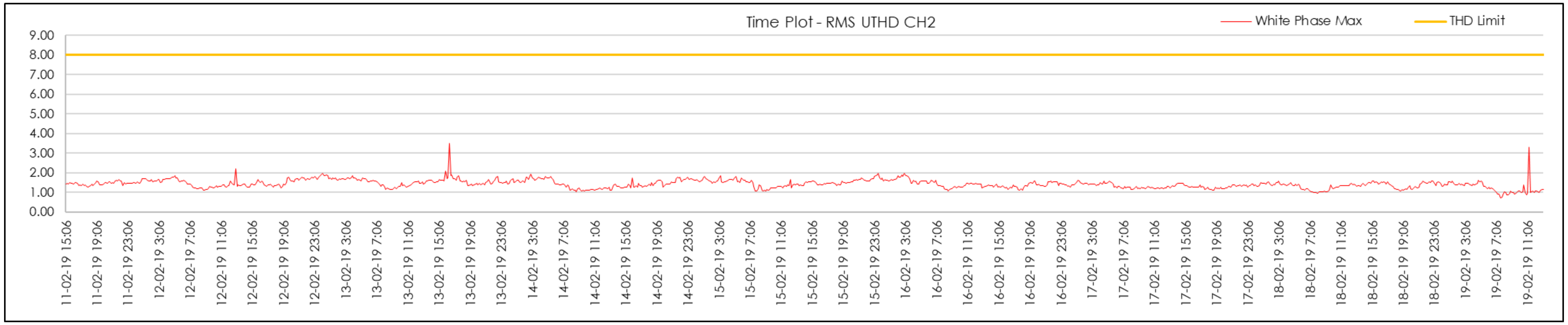

Figure 38 | TC1 Start U-THD measurements (White Phase)

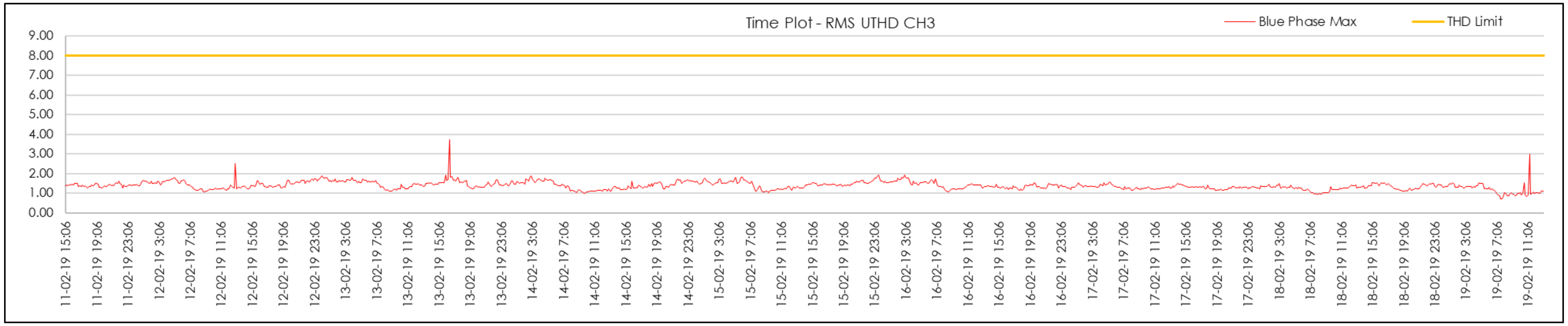

Figure 39 | TC1 Start U-THD measurements (Blue Phase)

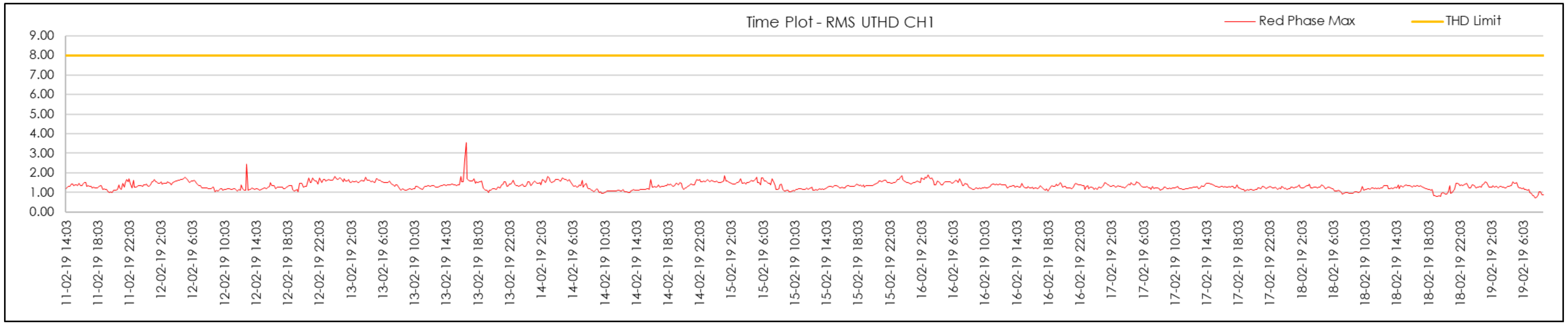

Figure 40 | TC1 End U-THD measurements (Red Phase)

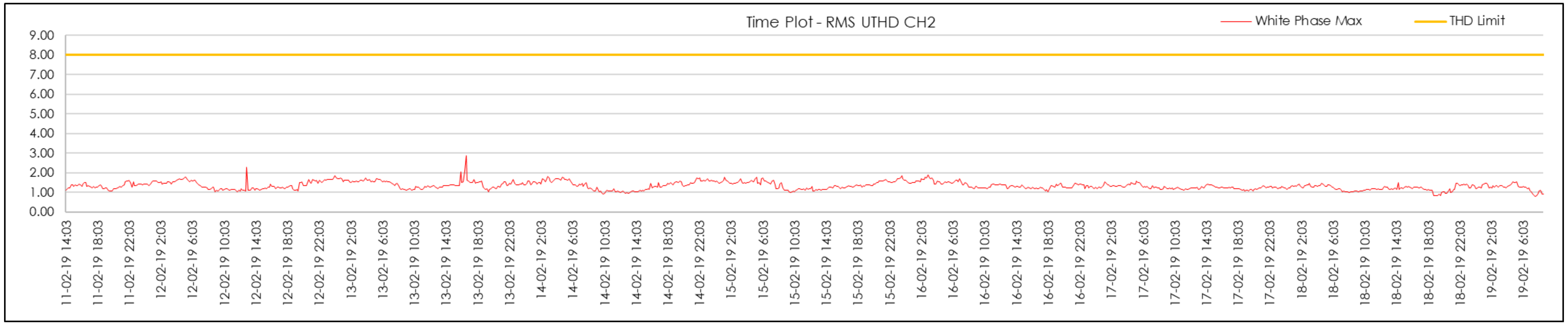

Figure 41 | TC1 End U-THD measurements (White Phase)

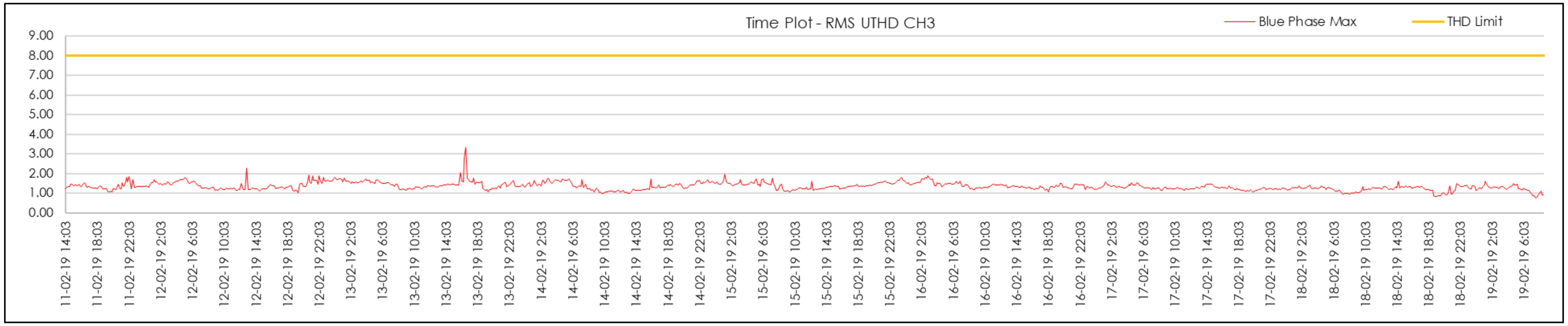

Figure 42 | TC1 End U-THD measurements (Blue Phase)

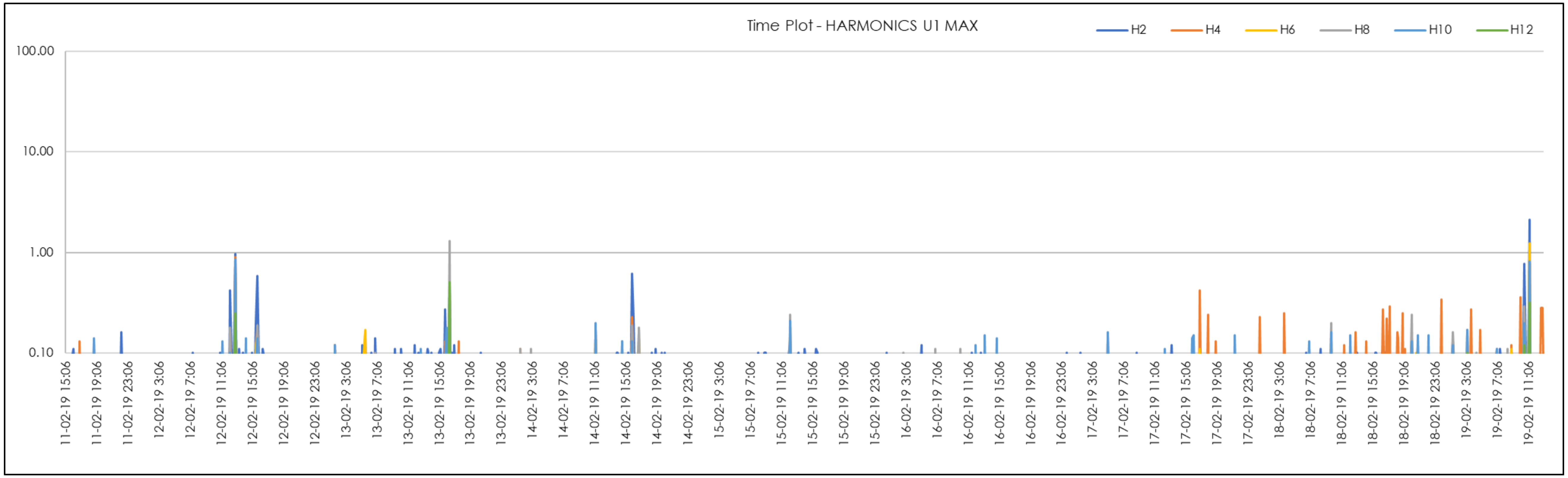

Figure 43 | TC1 Start Even 2nd-12th Harmonics (Red Phase)

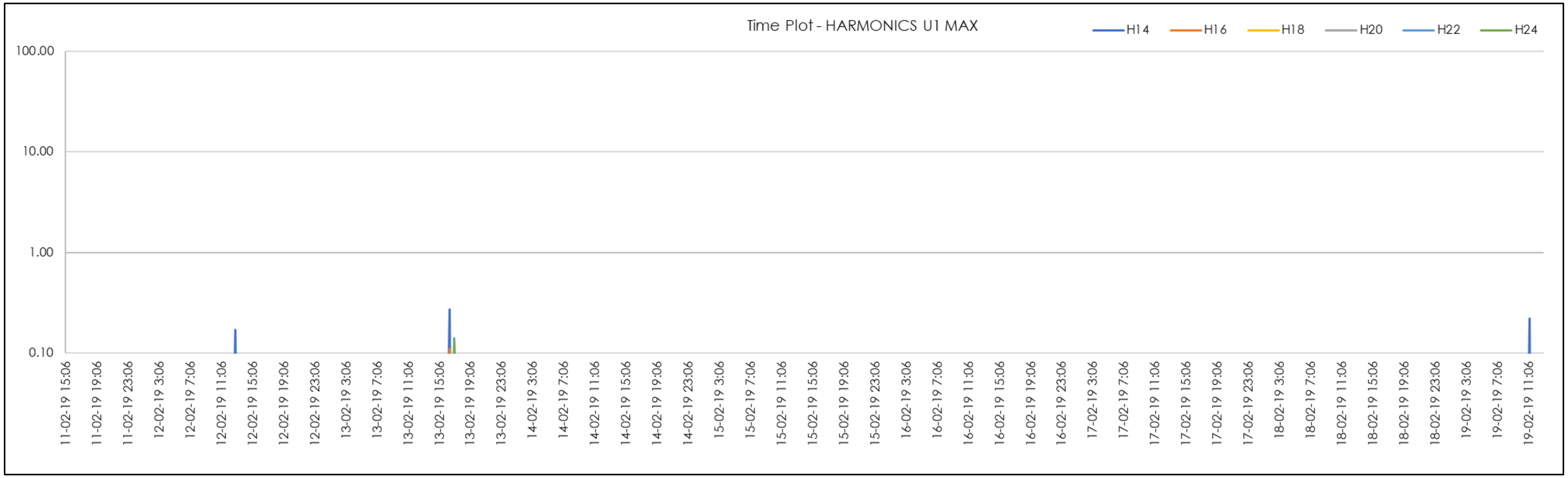

Figure 44 | TC1 Start Even 14th-24th Harmonics (Red Phase)

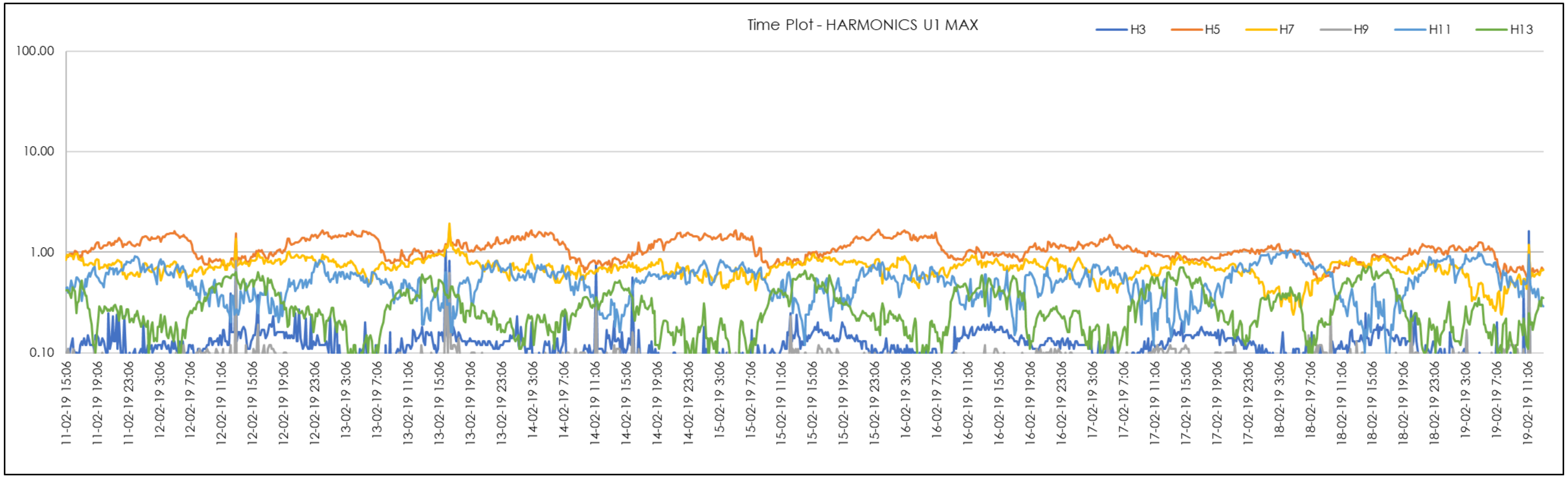

Figure 45 | TC1 Start Odd 3rd-13th Harmonics (Red Phase)

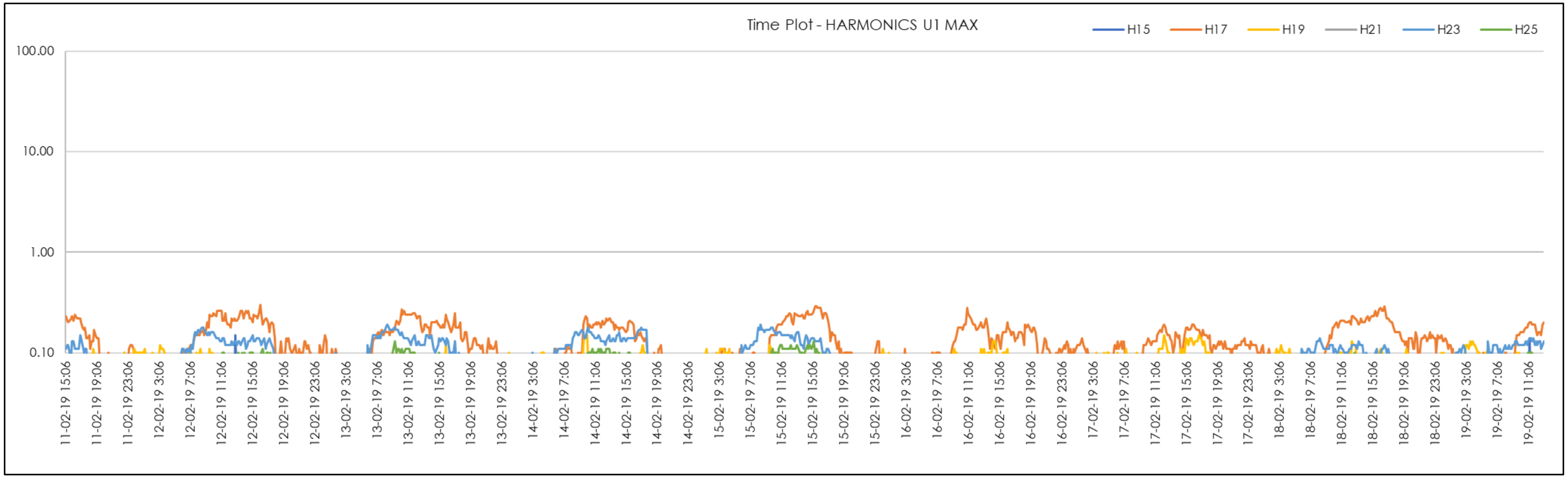

Figure 46 | TC1 Start Odd 15th-25th Harmonics (Red Phase)

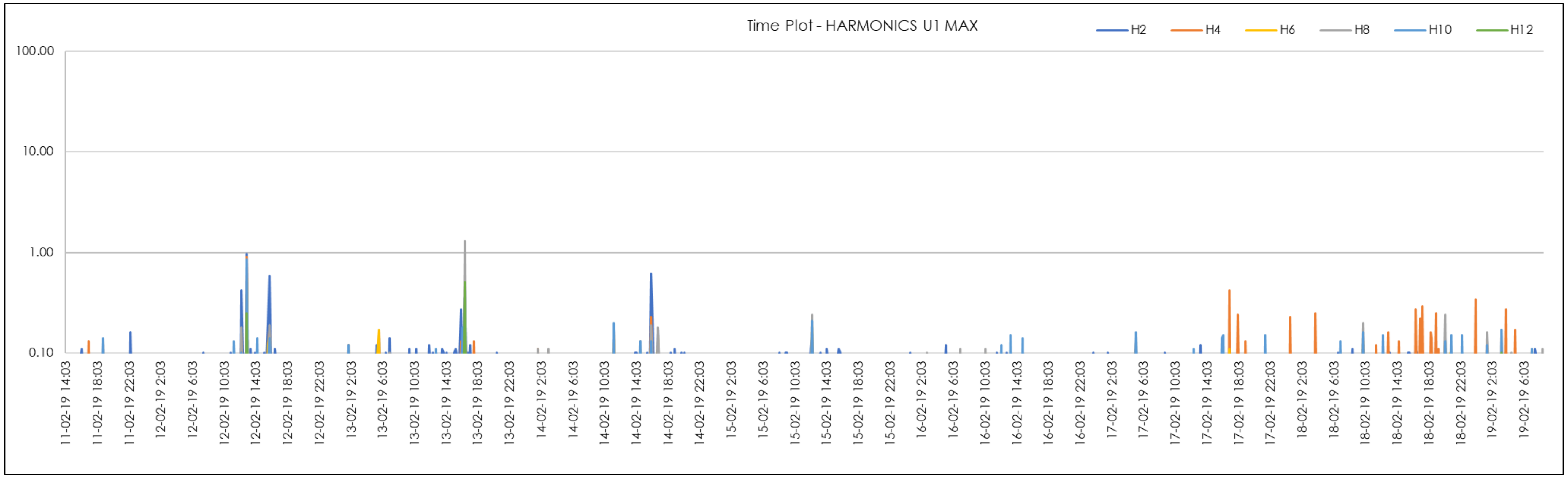

Figure 47 | TC1 End Even 2nd-12th Harmonics (Red Phase)

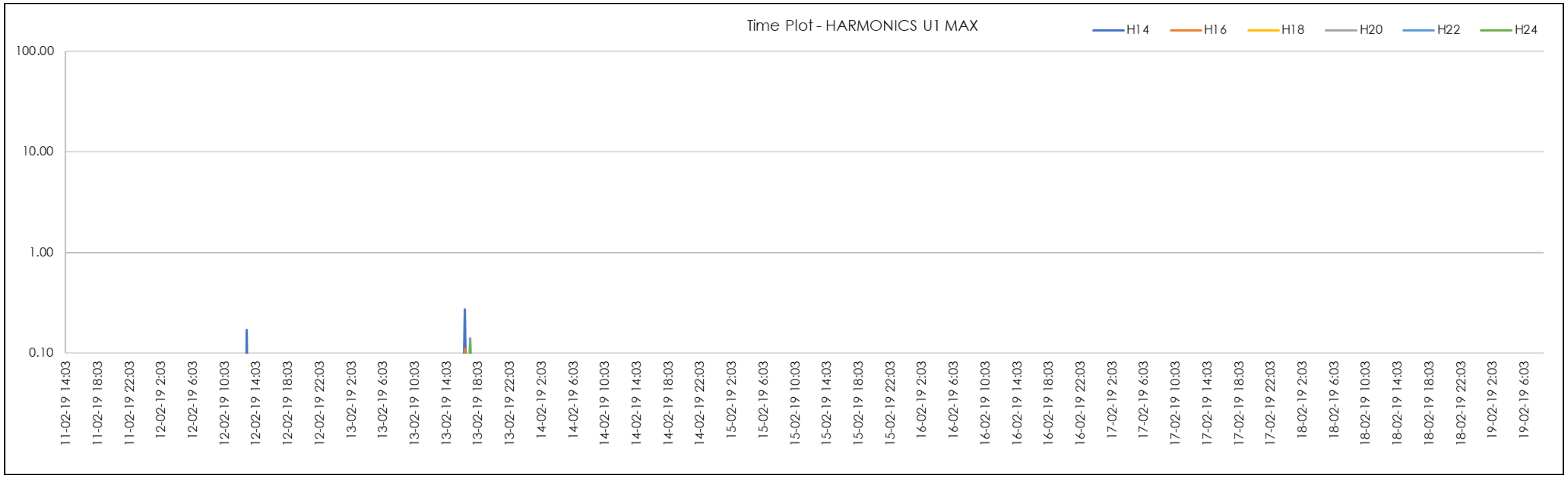

Figure 48 | TC1 End Even 14th-24th Harmonics (Red Phase)

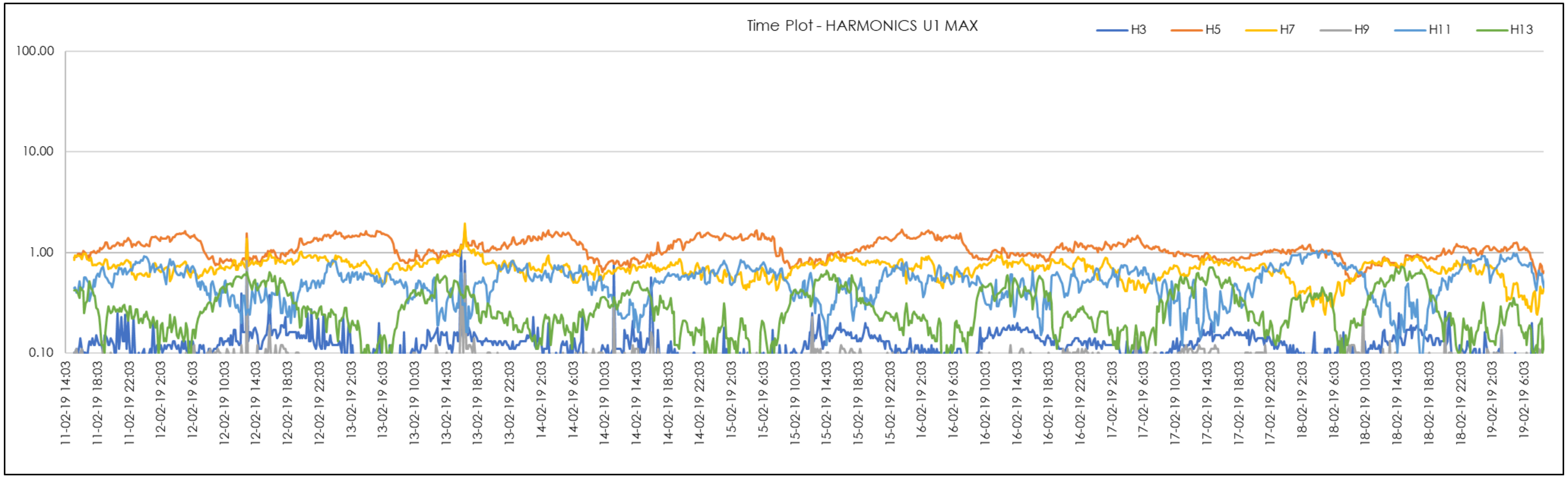

Figure 49 | TC1 End Odd 3rd-13th Harmonics (Red Phase)

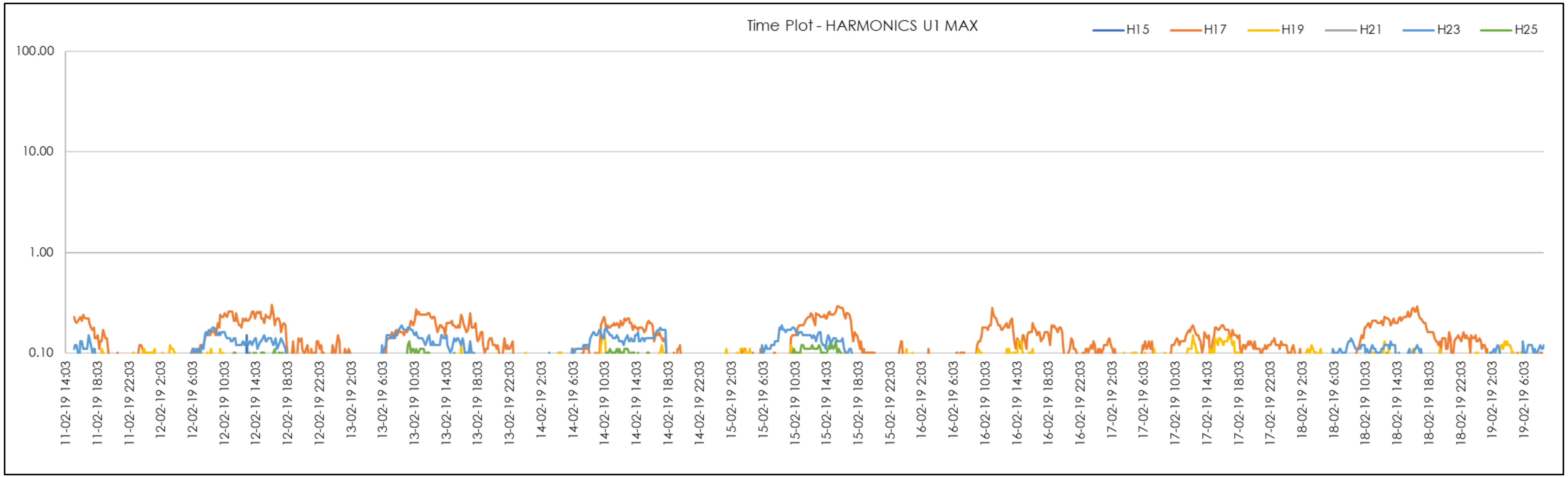

Figure 50 | TC1 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.2. FEEDER TC2 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

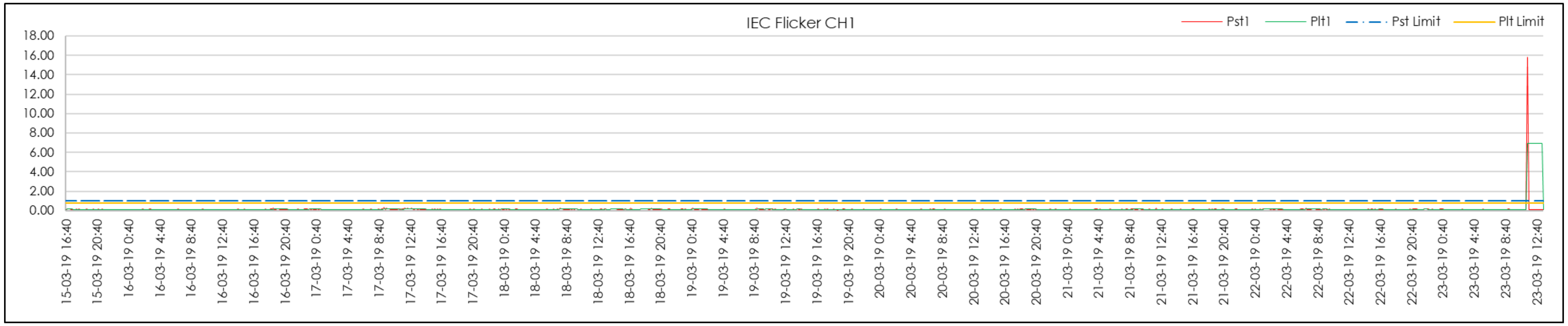

Figure 51 | TC2 Start Flicker measurements (Red Phase)

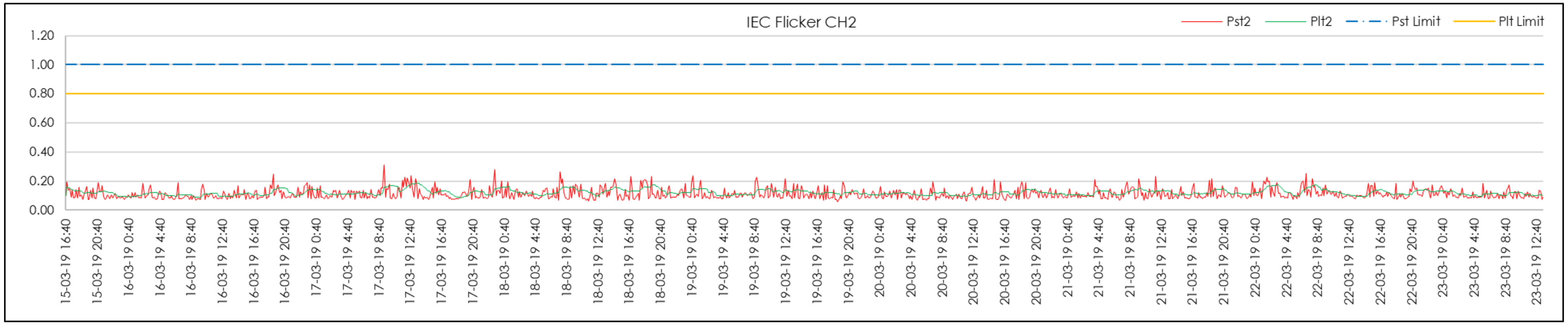

Figure 52 | TC2 Start Flicker measurements (White Phase)

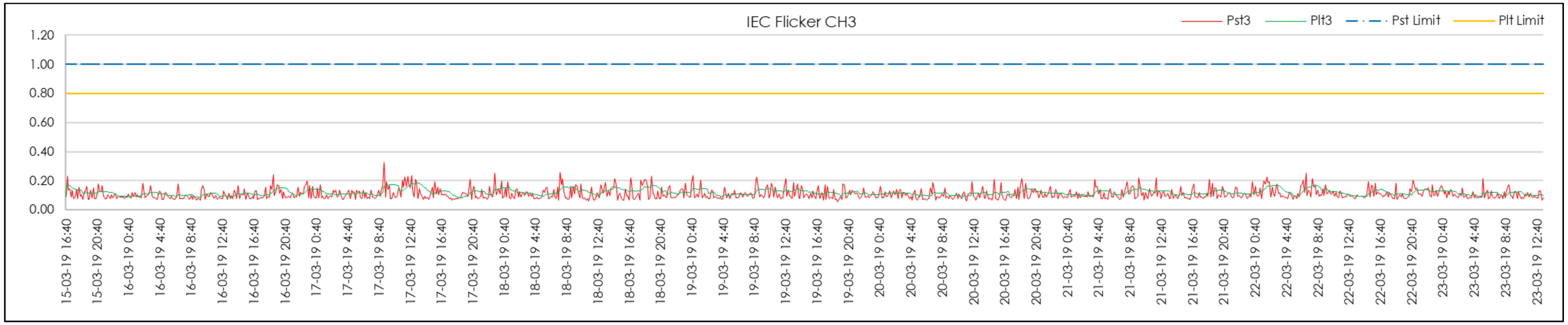

Figure 53 | TC2 Start Flicker measurements (Blue Phase)

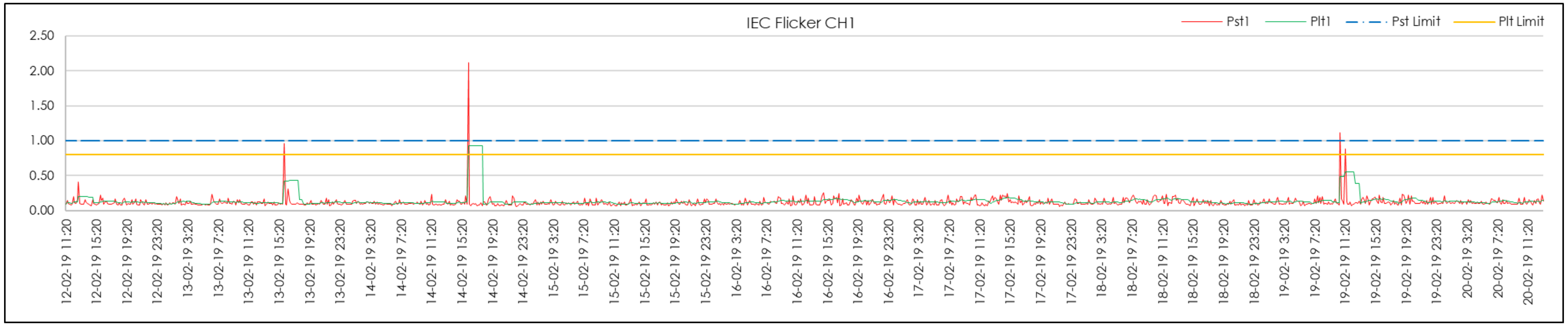

Figure 54 | TC2 End Flicker measurements (Red Phase)

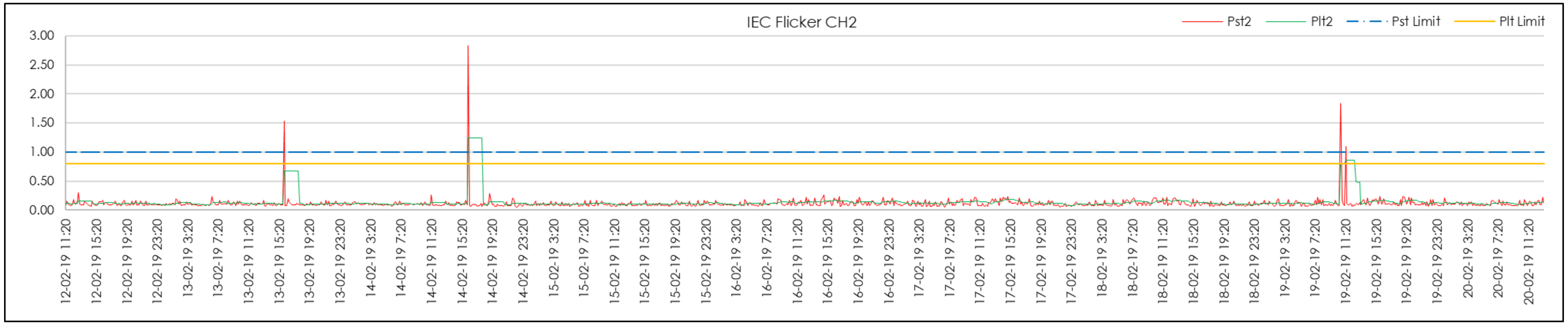

Figure 55 | TC2 End Flicker measurements (White Phase)

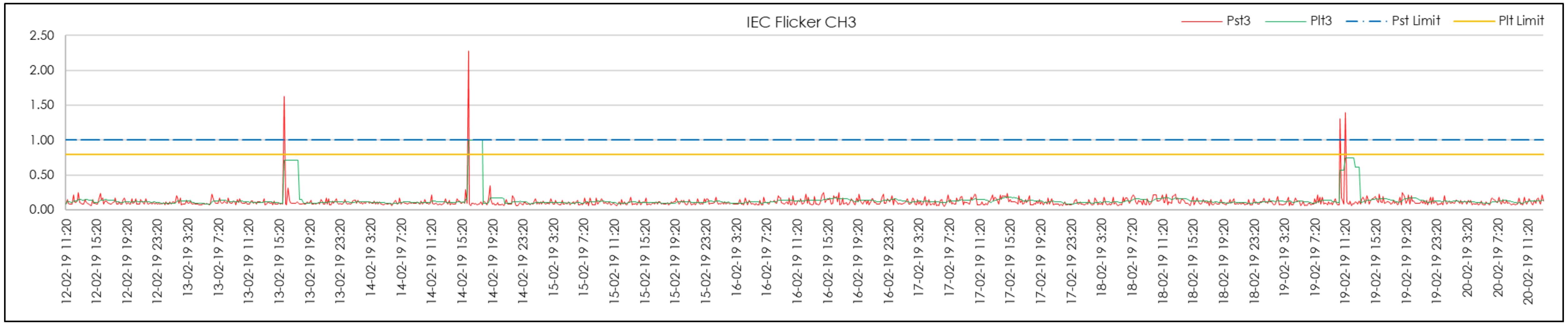

Figure 56 | TC2 End Flicker measurements (Blue Phase)

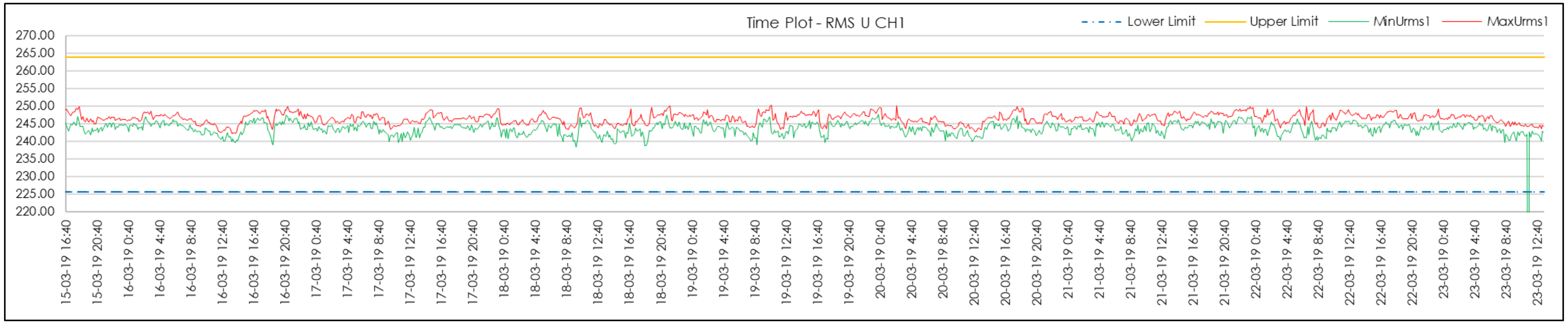

Figure 57 | TC2 Start Voltage measurements (Red Phase)

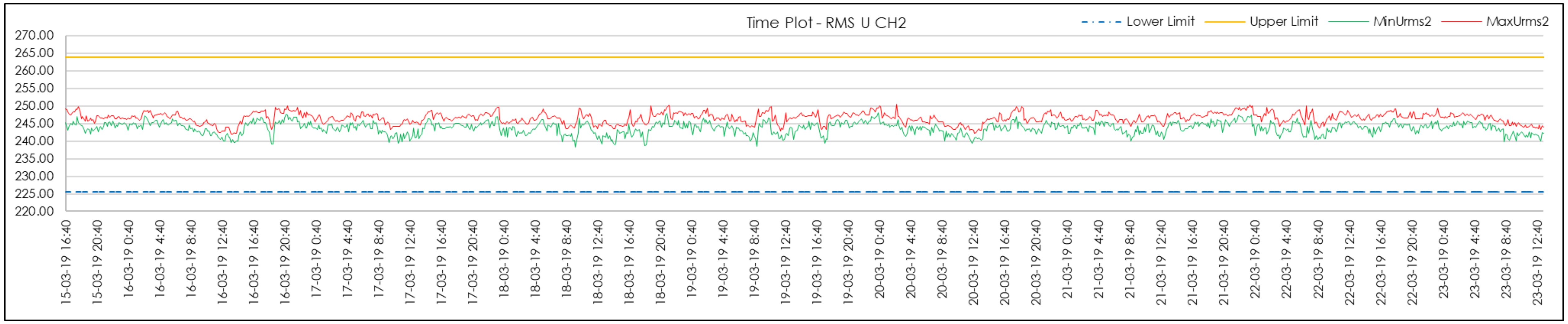

Figure 58 | TC2 Start Voltage measurements (White Phase)

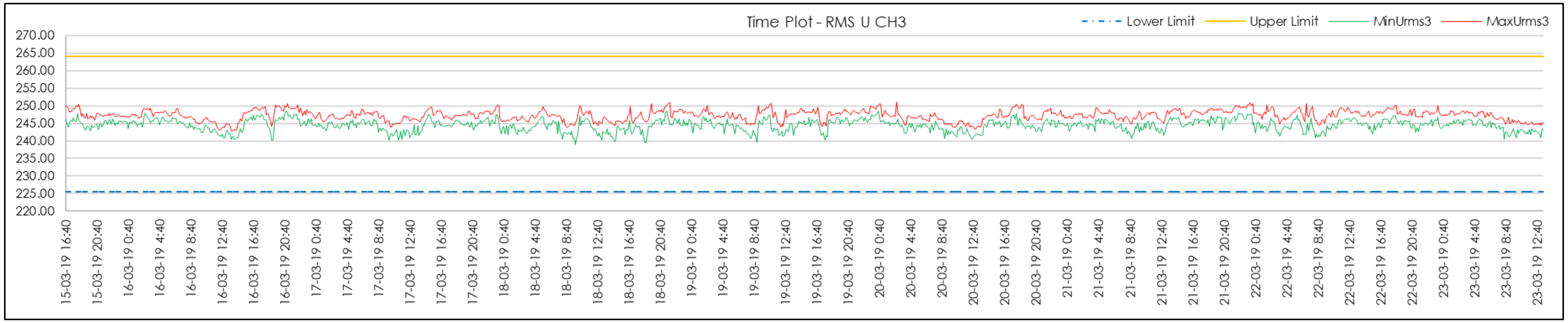

Figure 59 | TC2 Start Voltage measurements (Blue Phase)

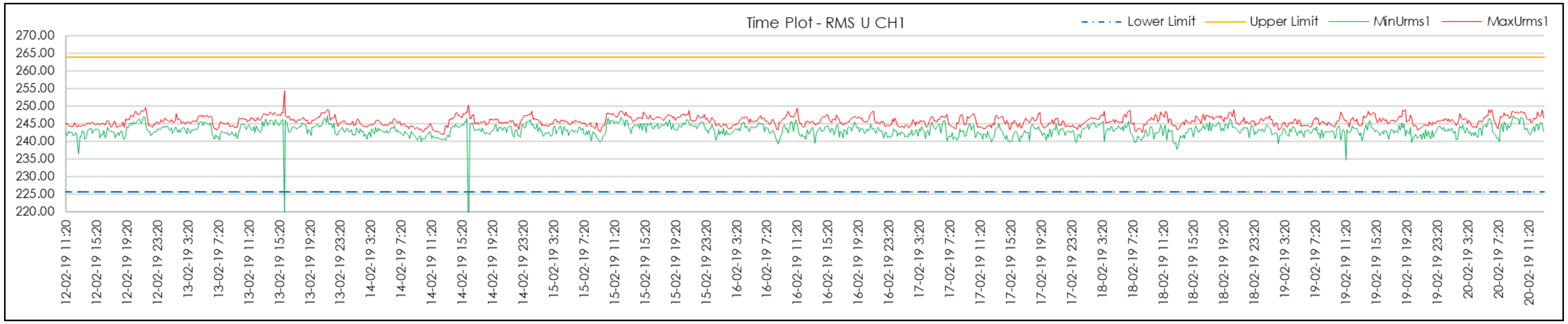

Figure 60 | TC2 End Voltage measurements (Red Phase)

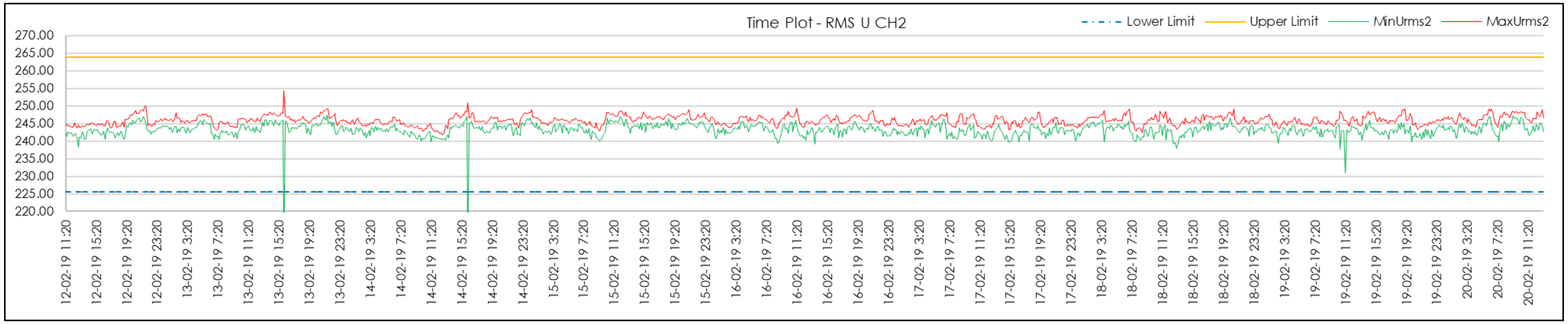

Figure 61 | TC2 End Voltage measurements (White Phase)

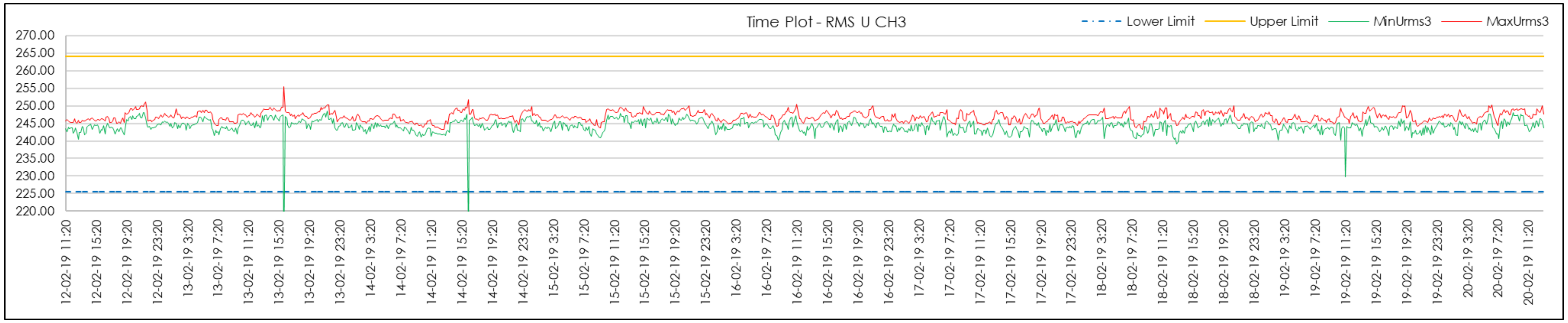

Figure 62 | TC2 End Voltage measurements (Blue Phase)

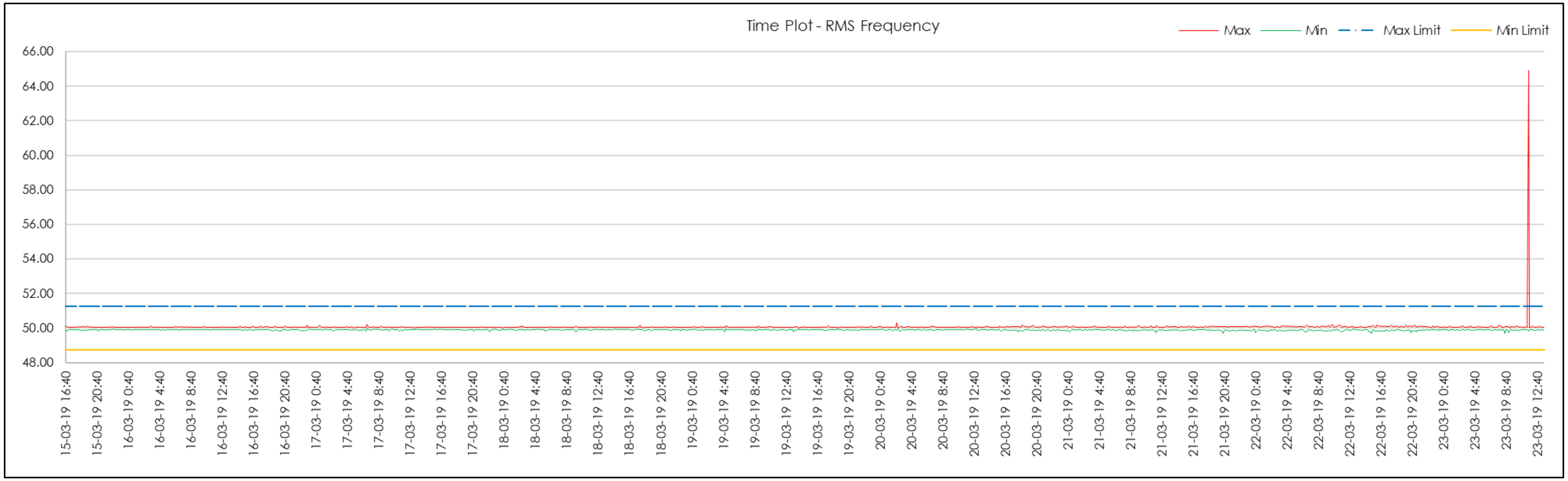

Figure 63 | TC2 Start Frequency measurements

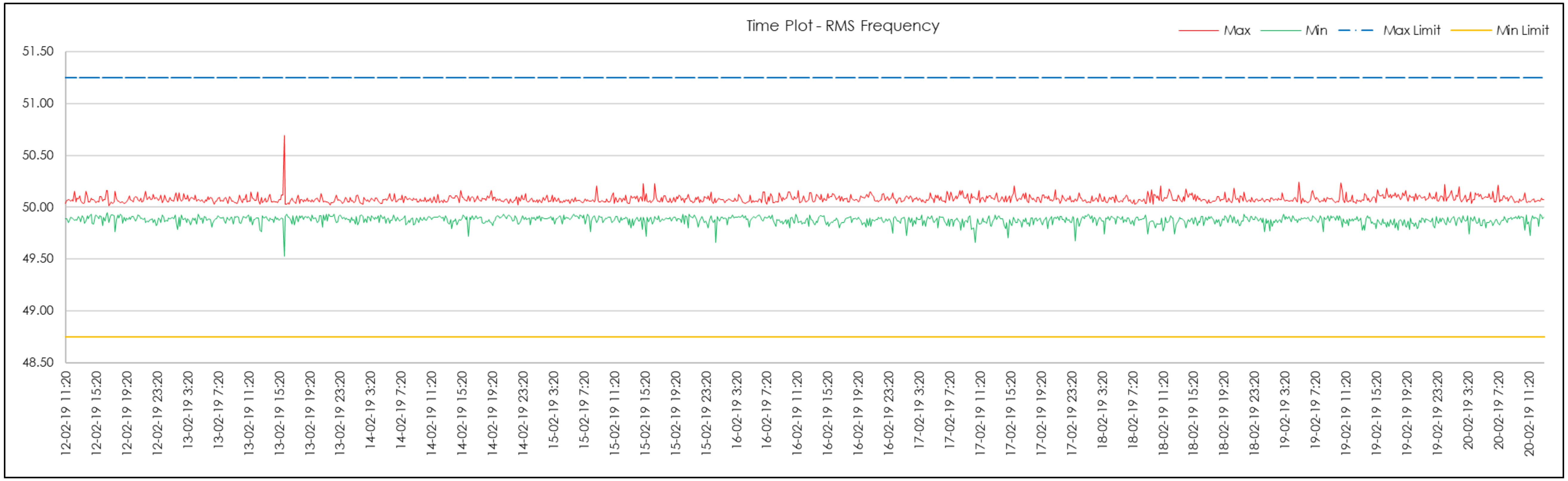

Figure 64 | TC2 End Frequency measurements

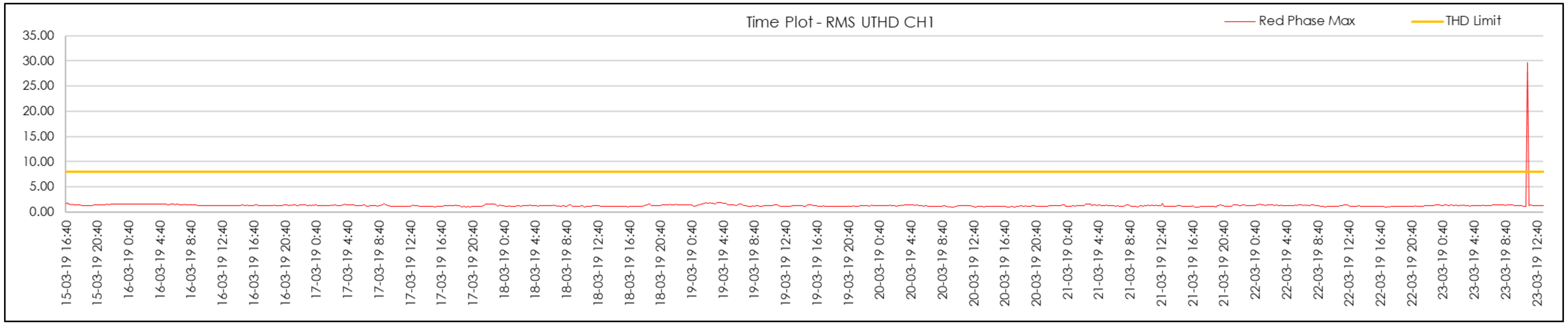

Figure 65 | TC2 Start U-THD measurements (Red Phase)

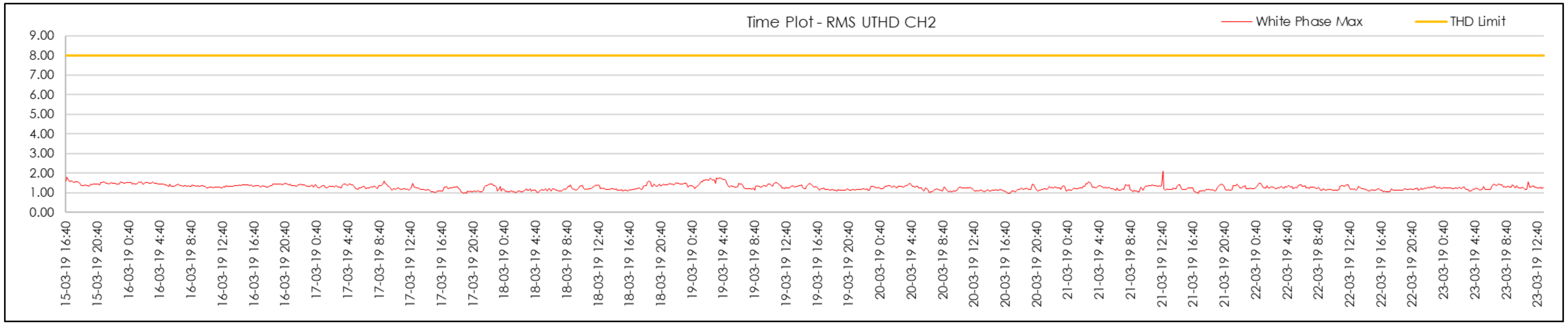

Figure 66 | TC2 Start U-THD measurements (White Phase)

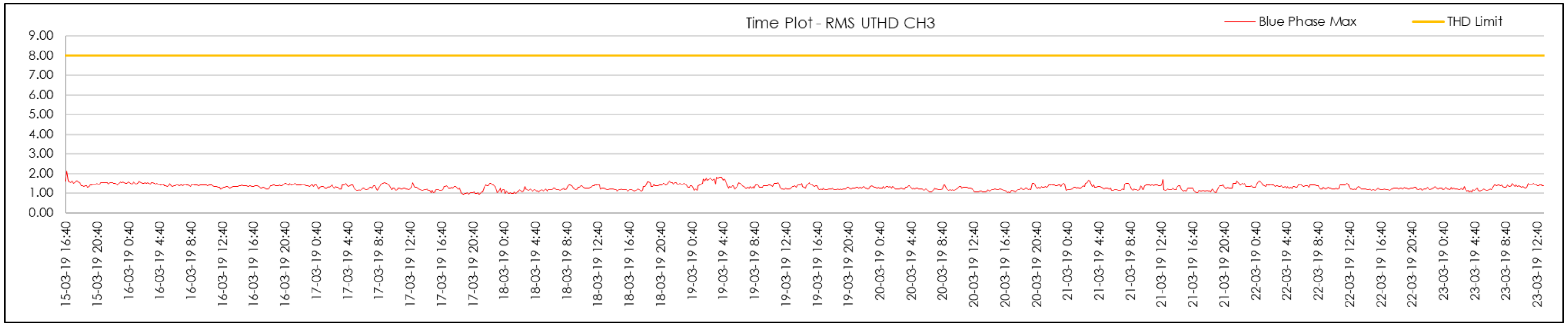

Figure 67 | TC2 Start U-THD measurements (Blue Phase)

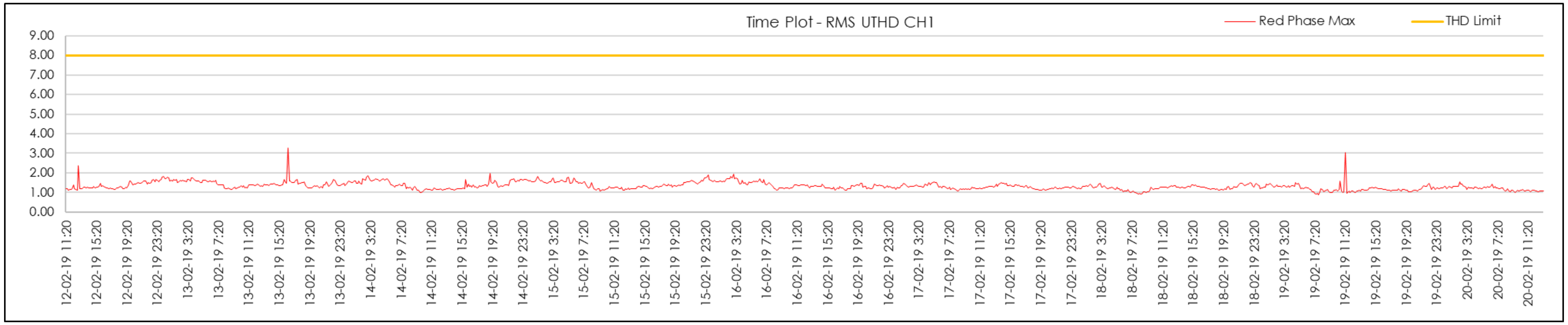

Figure 68 | TC2 End U-THD measurements (Red Phase)

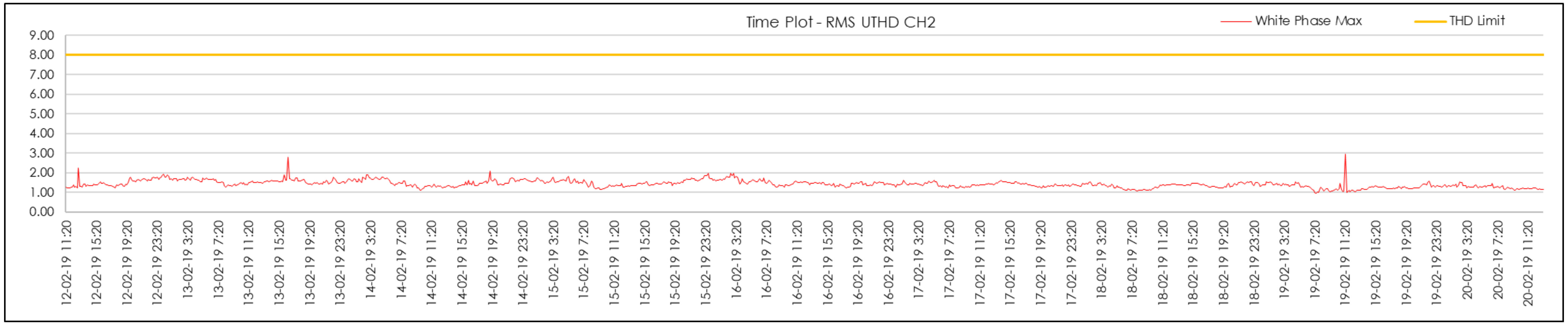

Figure 69 | TC2 End U-THD measurements (White Phase)

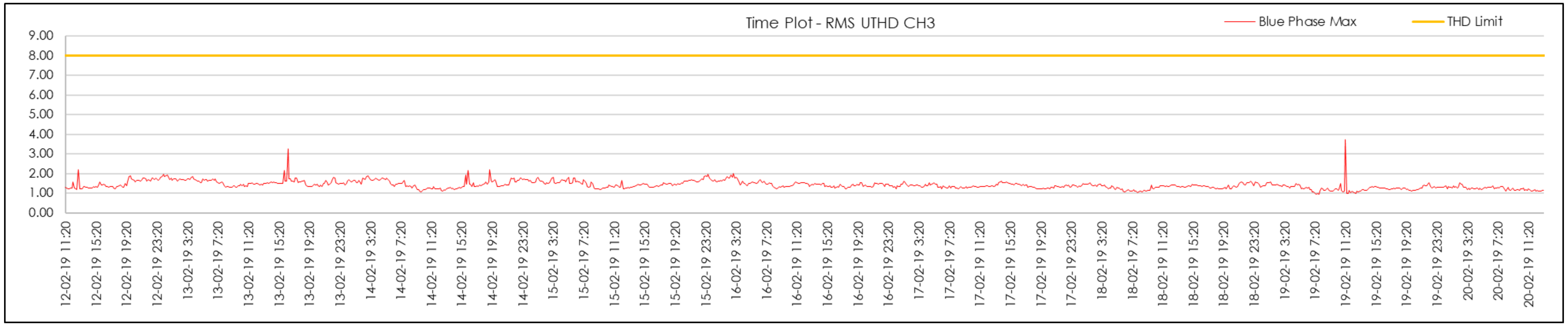

Figure 70 | TC2 End U-THD measurements (Blue Phase)

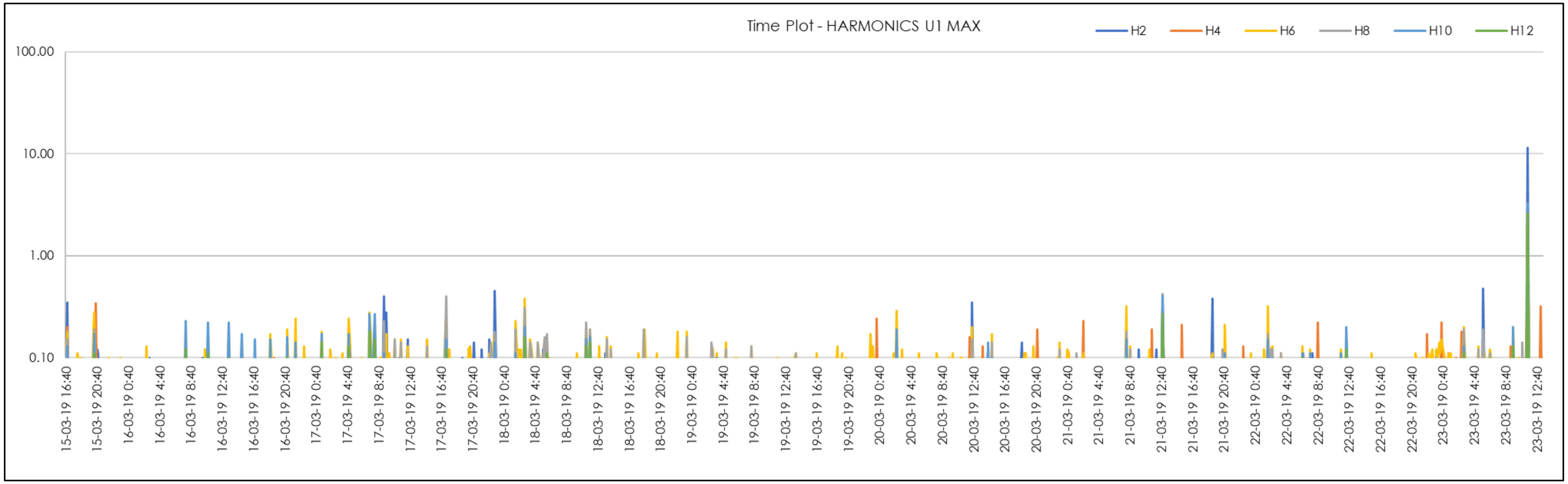

Figure 71 | TC2 Start Even 2nd-12th Harmonics (Red Phase)

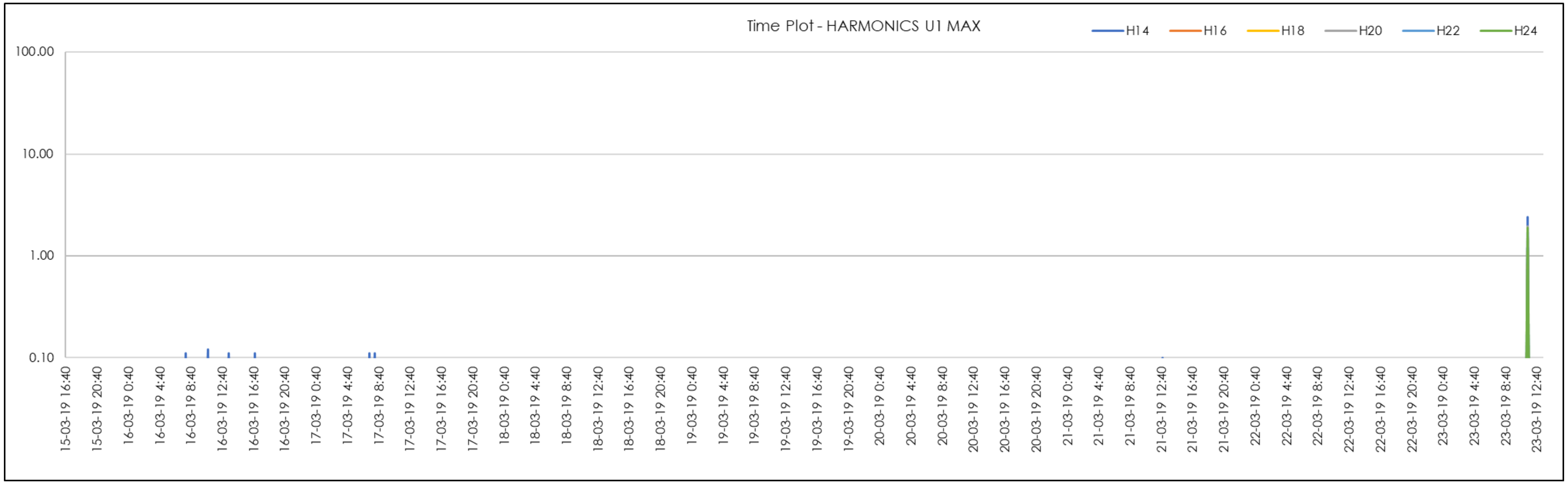

Figure 72 | TC2 Start Even 14th-24th Harmonics (Red Phase)

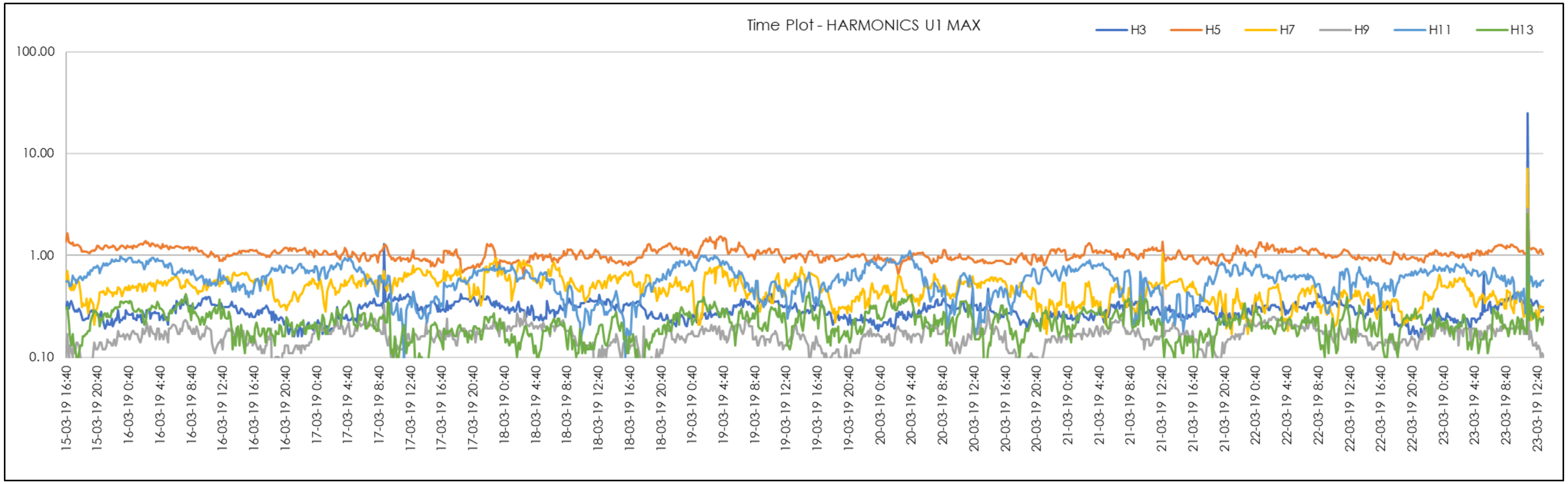

Figure 73 | TC2 Start Odd 3rd-13th Harmonics (Red Phase)

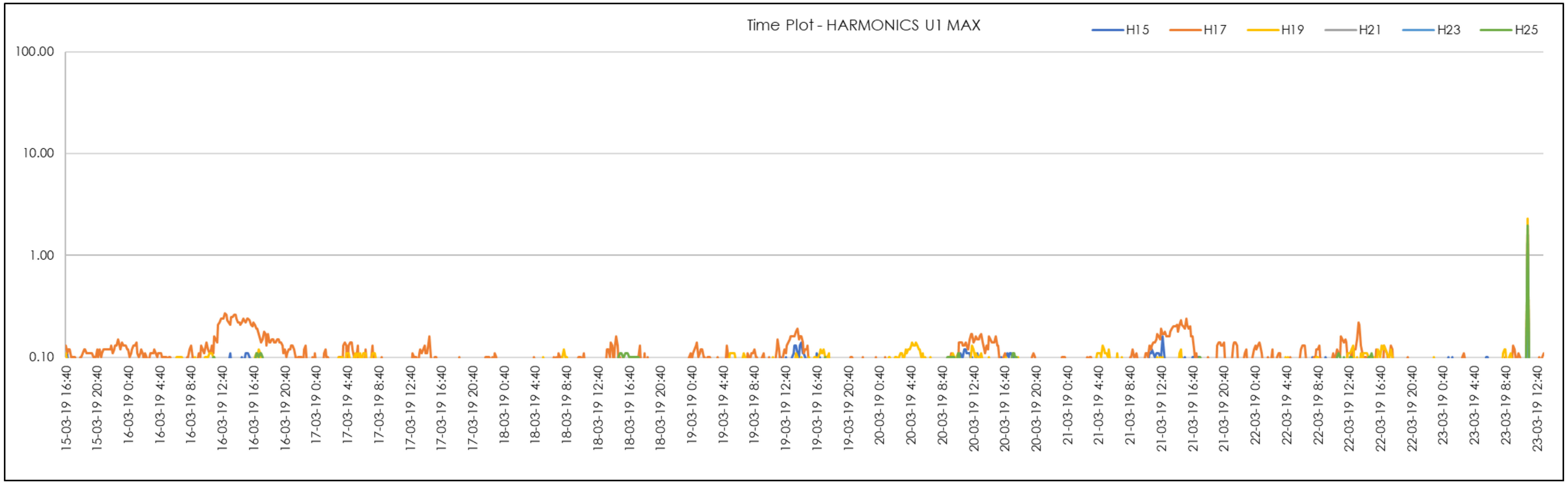

Figure 74 | TC2 Start Odd 15th-25th Harmonics (Red Phase)

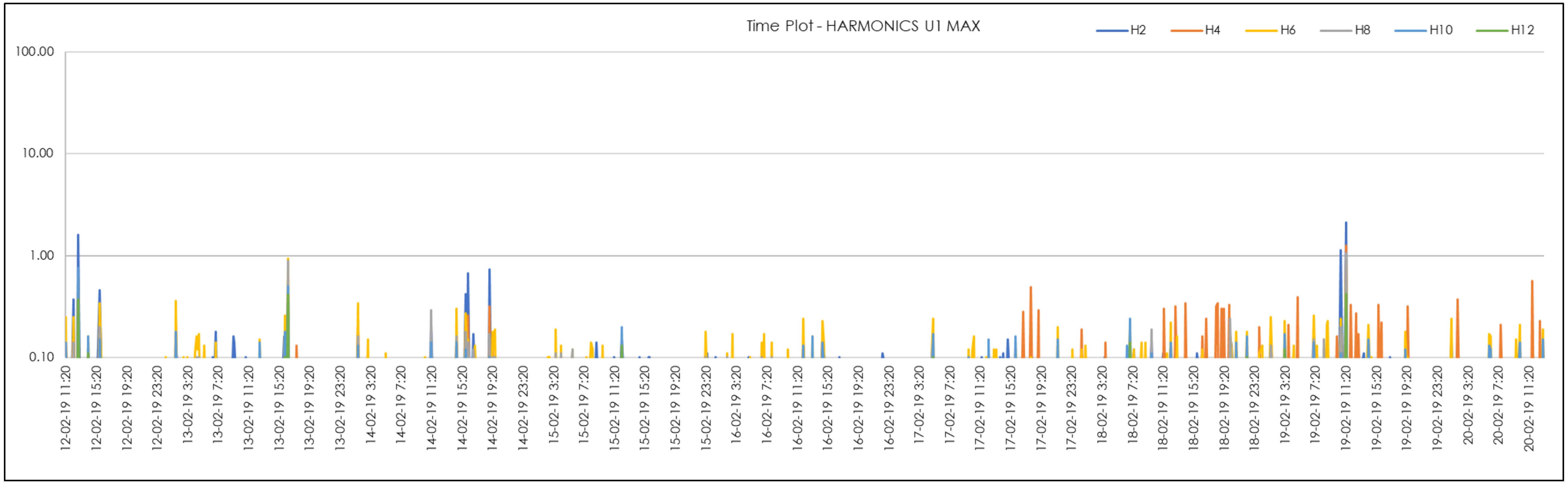

Figure 75 | TC2 End Even 2nd-12th Harmonics (Red Phase)

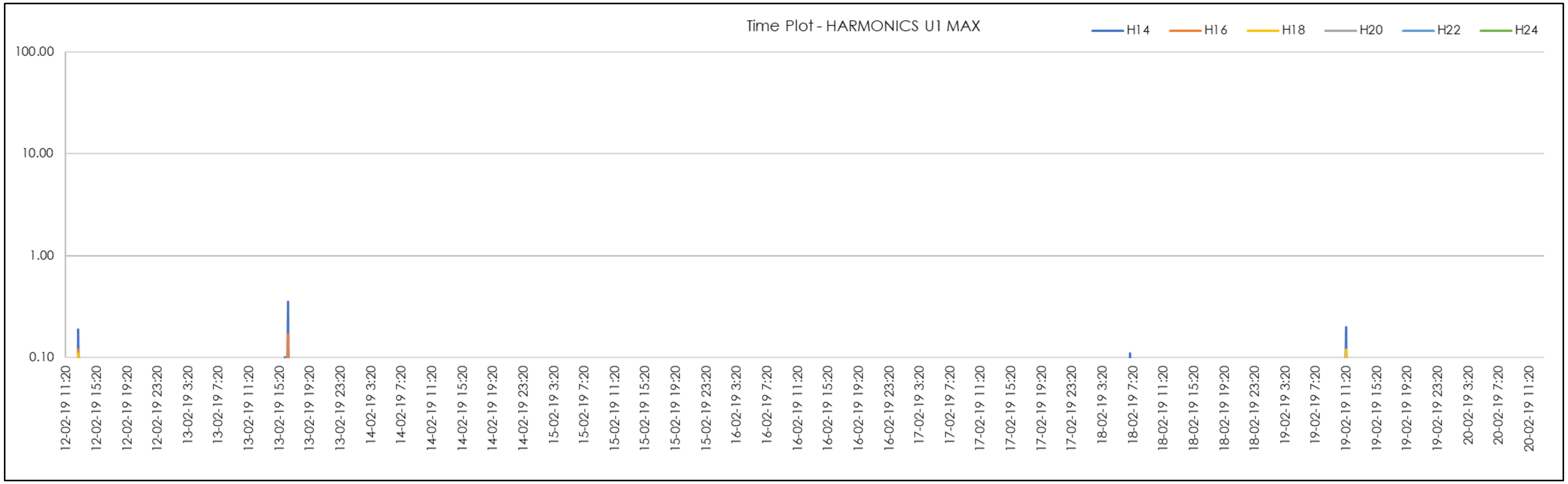

Figure 76 | TC2 End Even 14th-24th Harmonics (Red Phase)

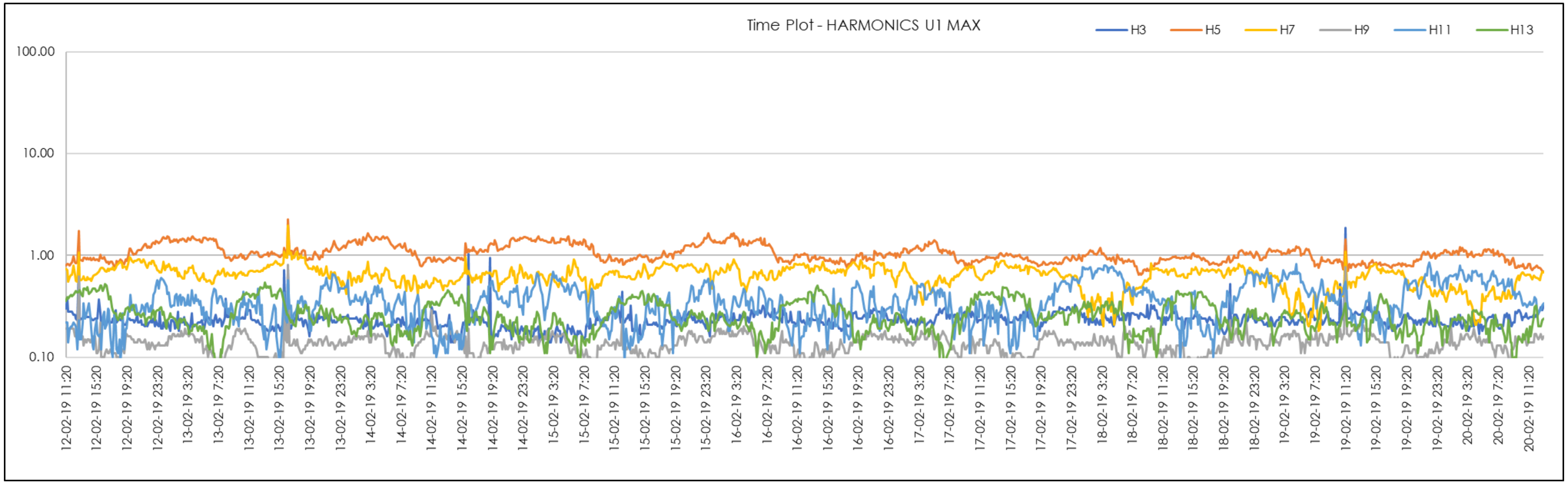

Figure 77 | TC2 End Odd 3rd-13th Harmonics (Red Phase)

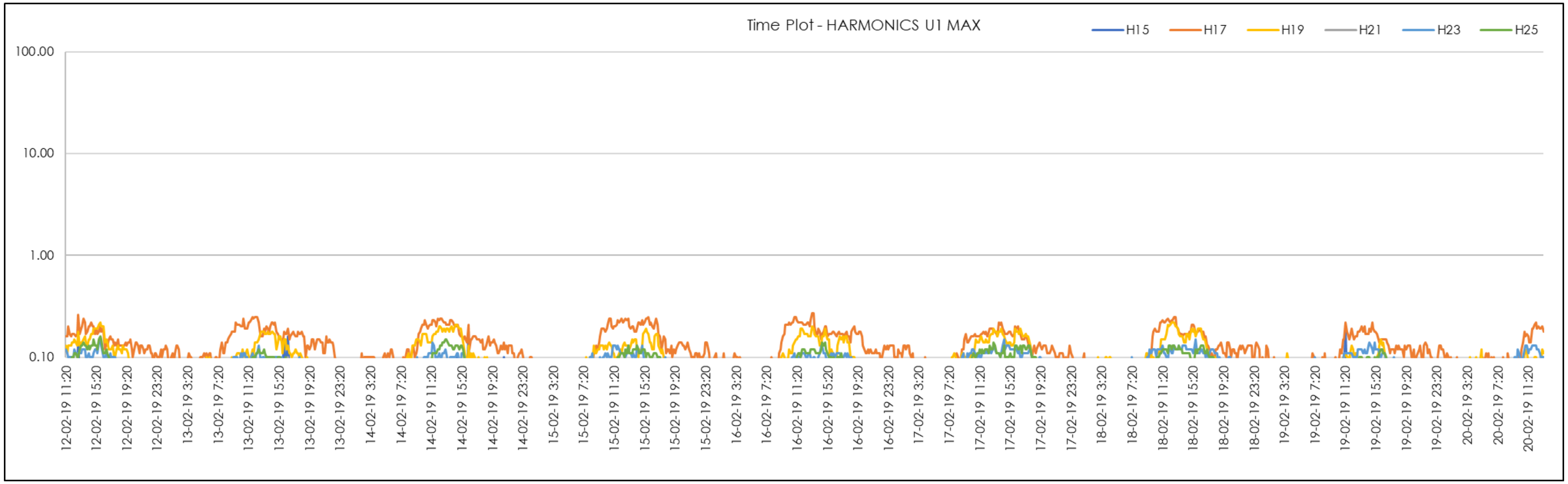

Figure 78 | TC2 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.3. FEEDER TC3 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

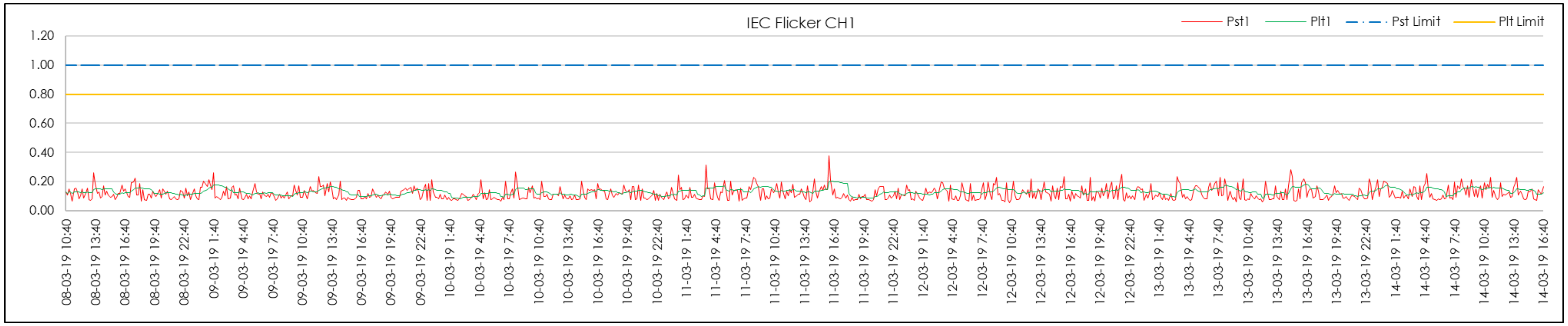

Figure 79 | TC3 Start Flicker measurements (Red Phase)

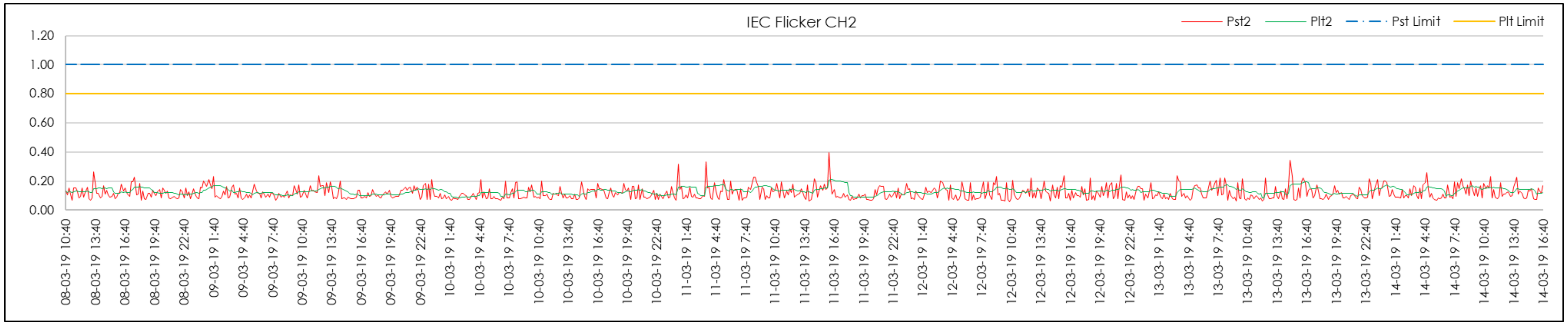

Figure 80 | TC3 Start Flicker measurements (White Phase)

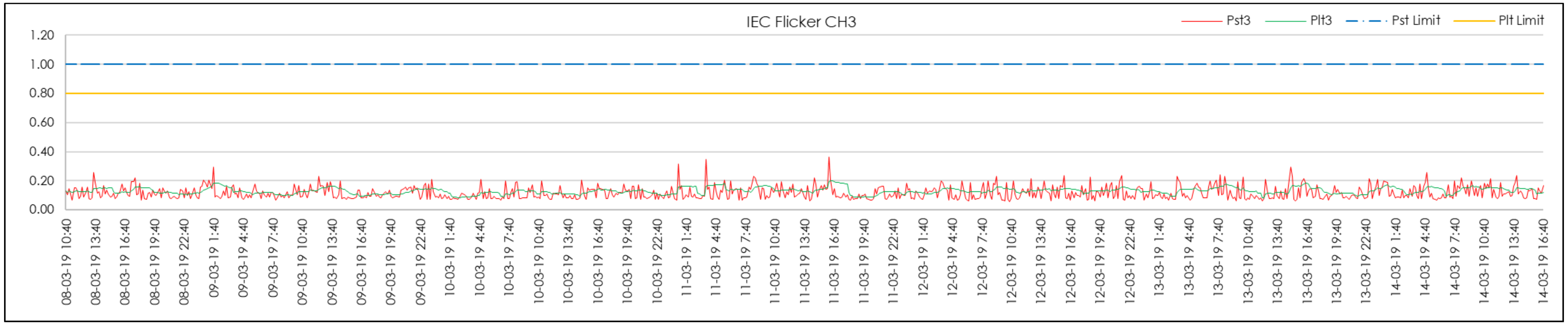

Figure 81 | TC3 Start Flicker measurements (Blue Phase)

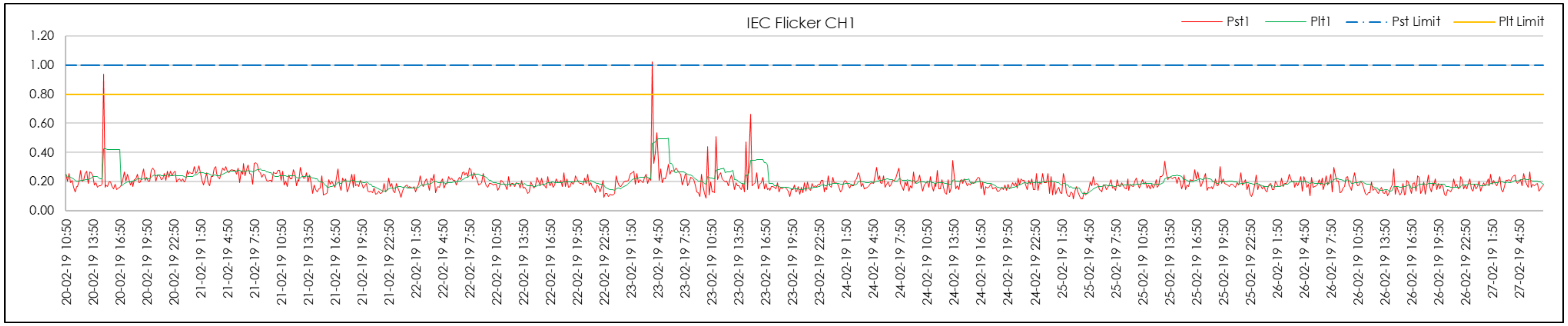

Figure 82 | TC3 End Flicker measurements (Red Phase)

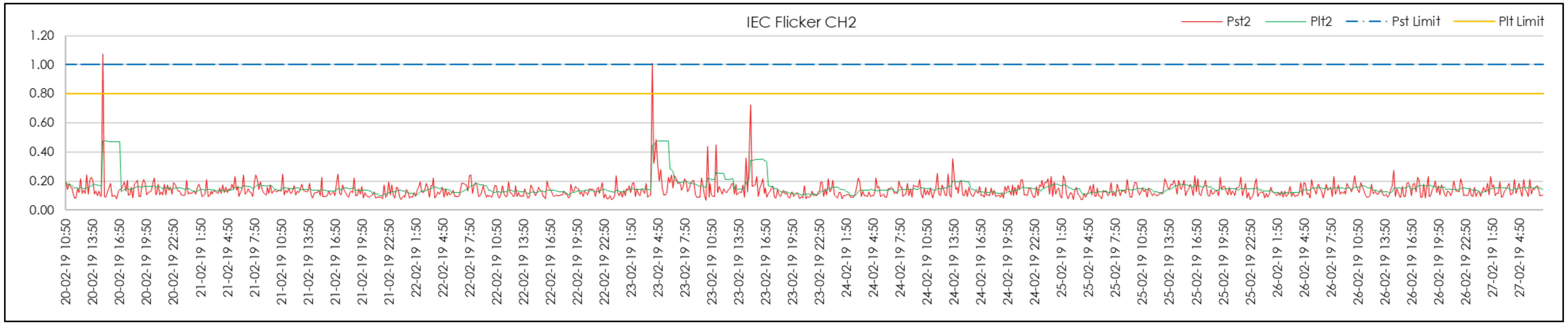

Figure 83 | TC3 End Flicker measurements (White Phase)

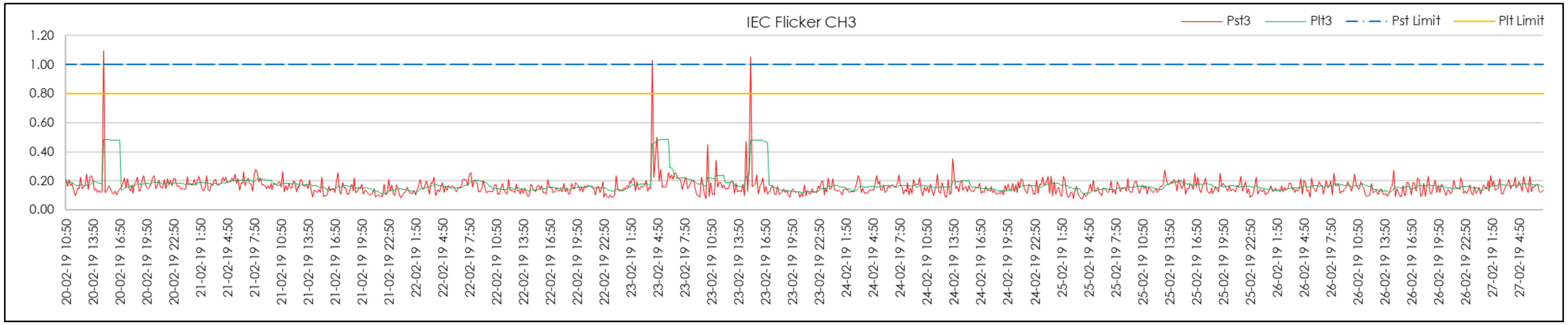

Figure 84 | TC3 End Flicker measurements (Blue Phase)

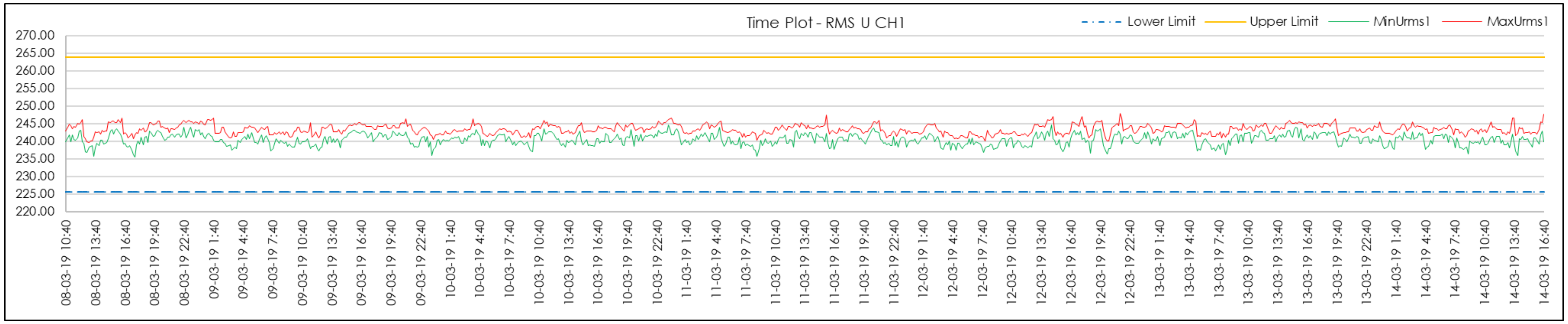

Figure 85 | TC3 Start Voltage measurements (Red Phase)

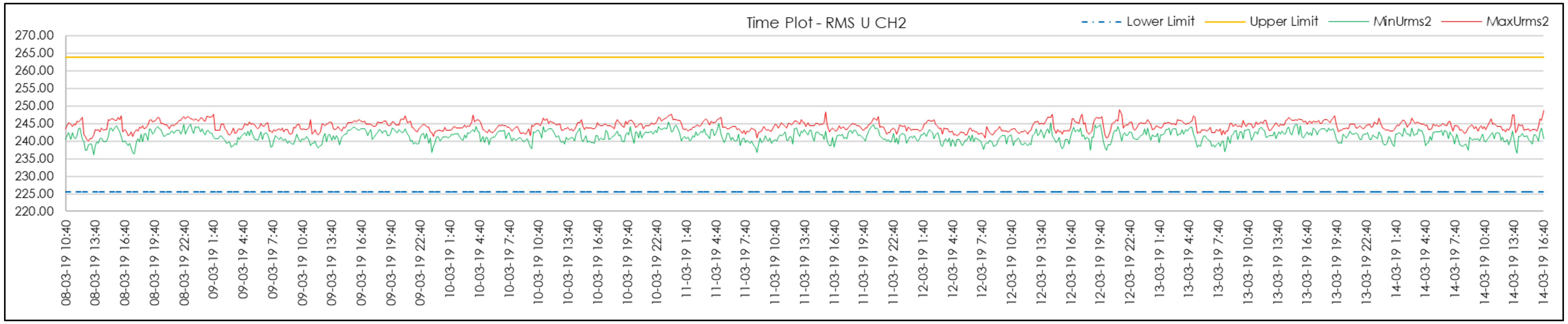

Figure 86 | TC3 Start Voltage measurements (White Phase)

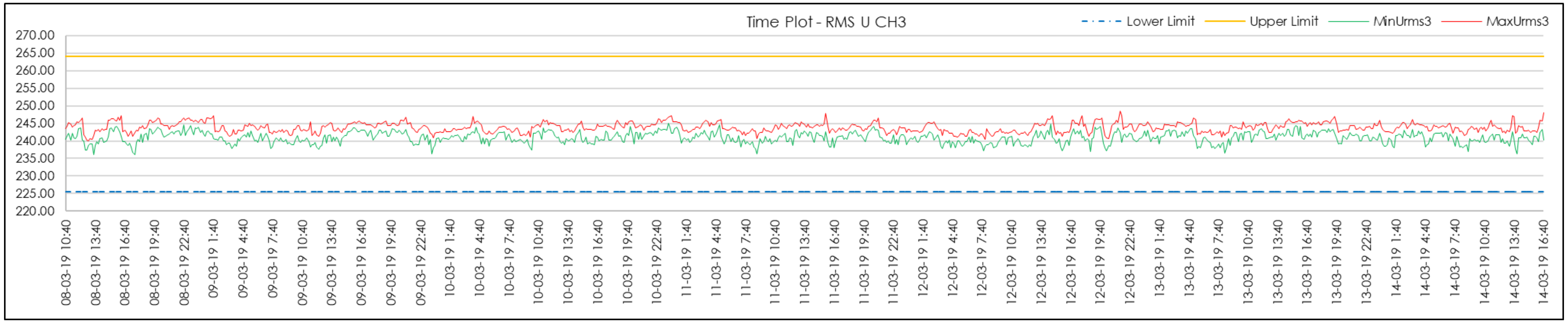

Figure 87 | TC3 Start Voltage measurements (Blue Phase)

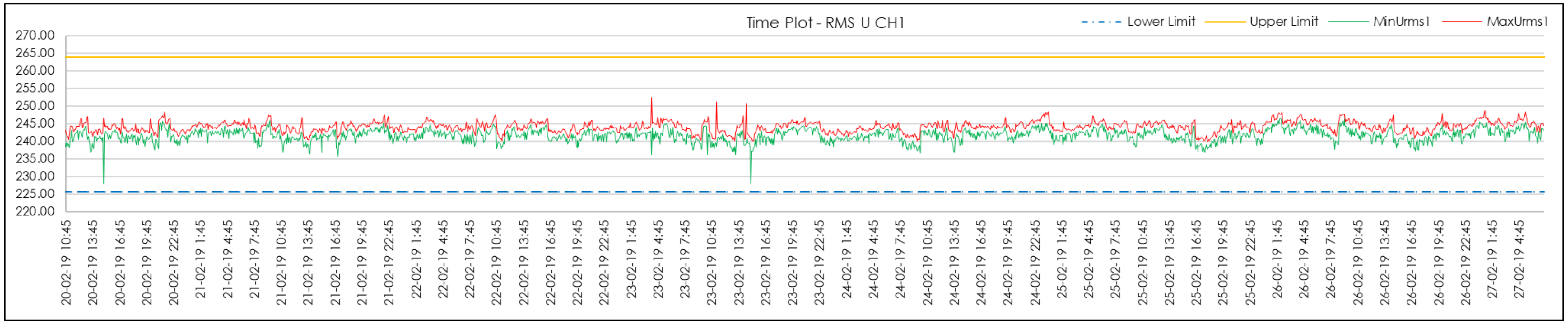

Figure 88 | TC3 End Voltage measurements (Red Phase)

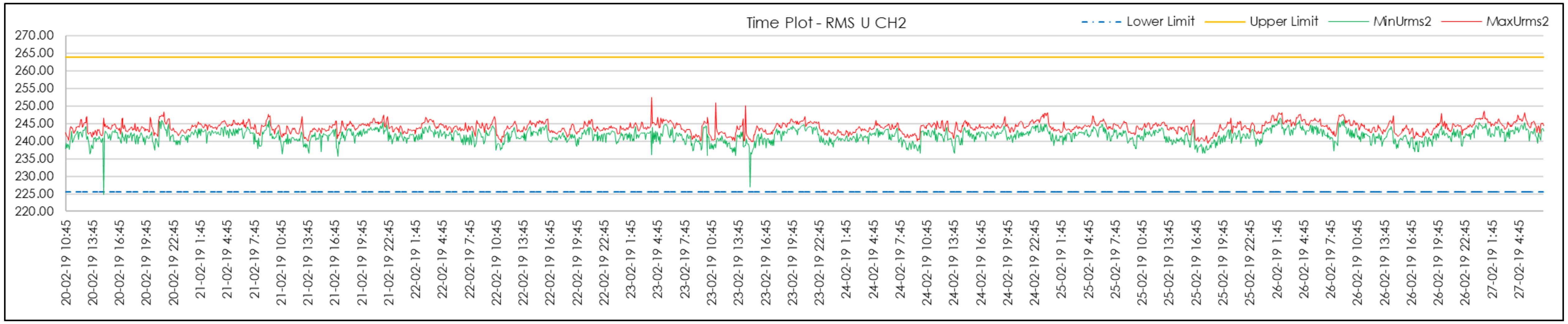

Figure 89 | TC3 End Voltage measurements (White Phase)

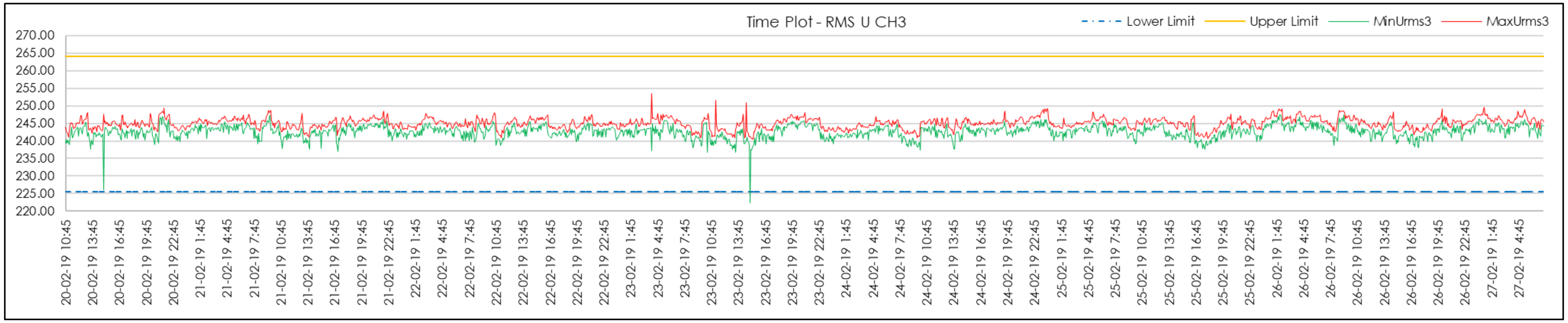

Figure 90 | TC3 End Voltage measurements (Blue Phase)

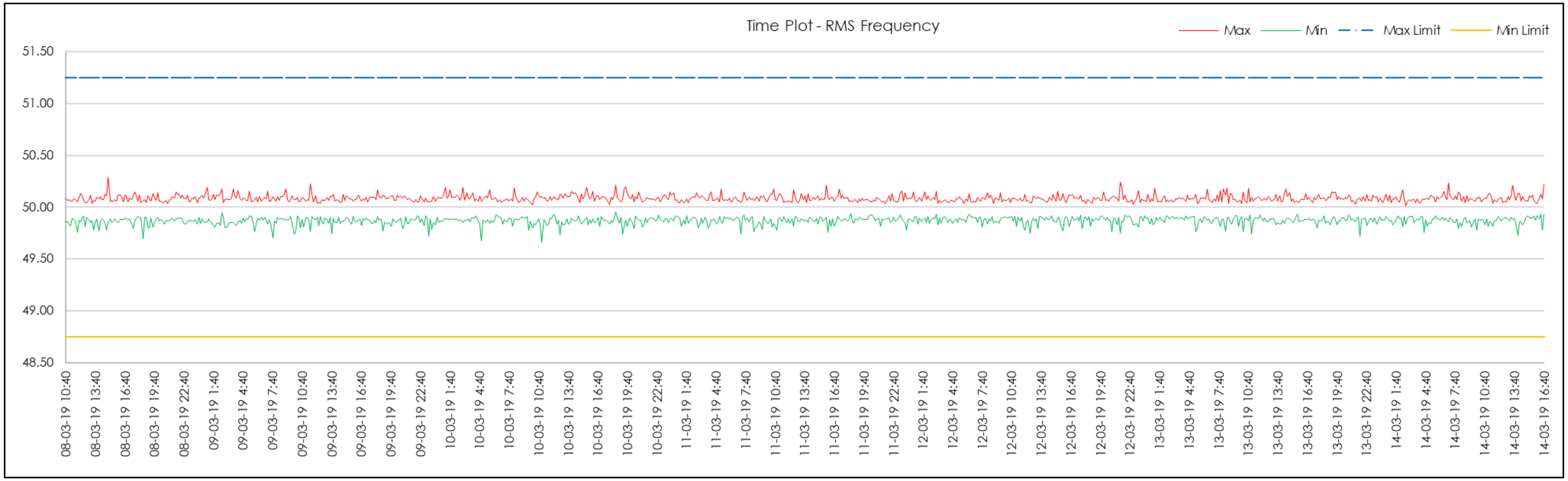

Figure 91 | TC3 Start Frequency measurements

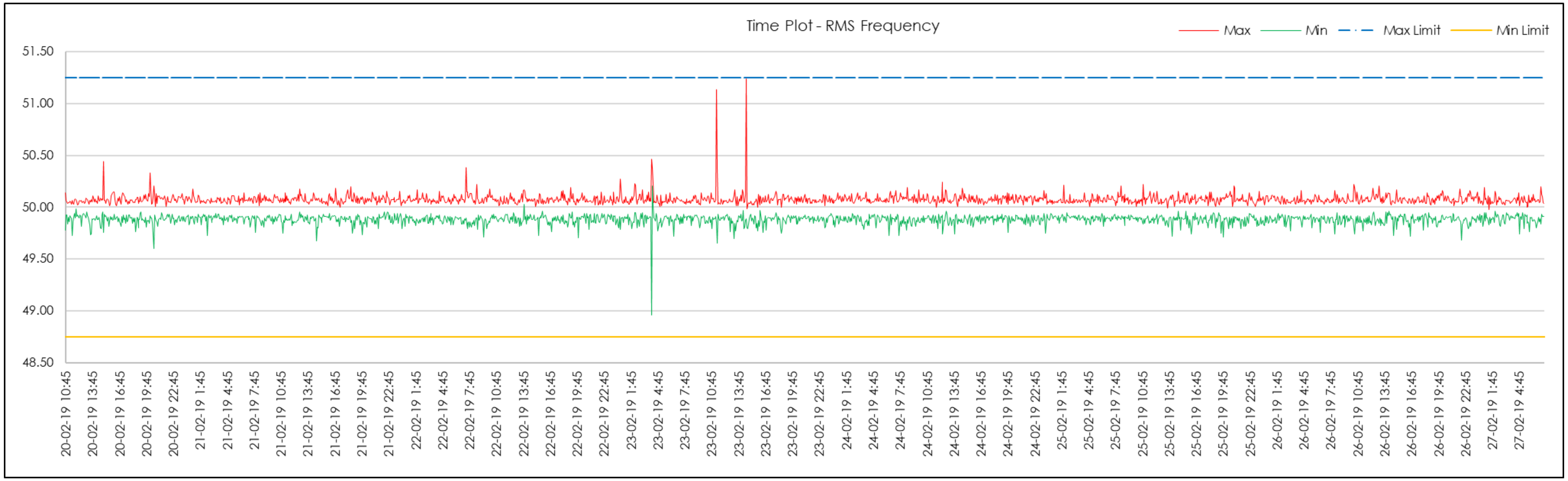

Figure 92 | TC3 End Frequency measurements

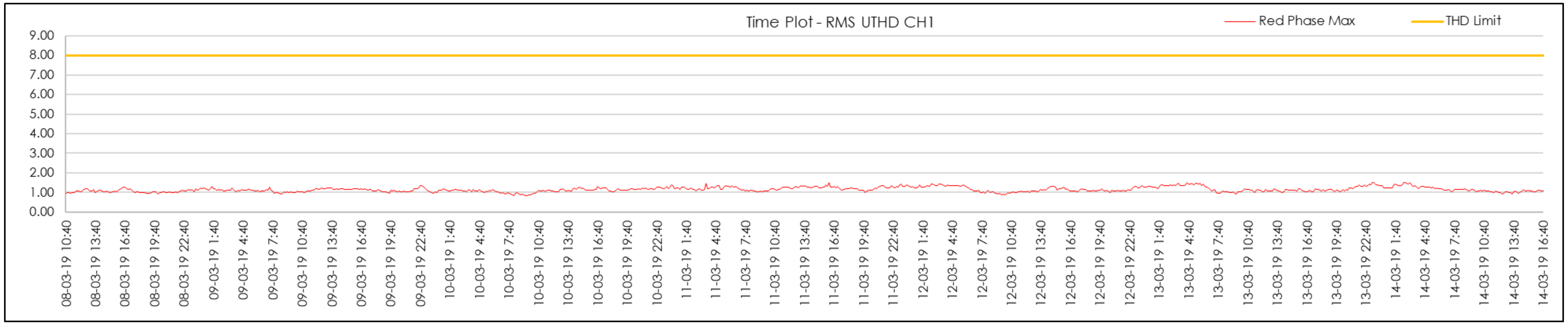

Figure 93 | TC3 Start U-THD measurements (Red Phase)

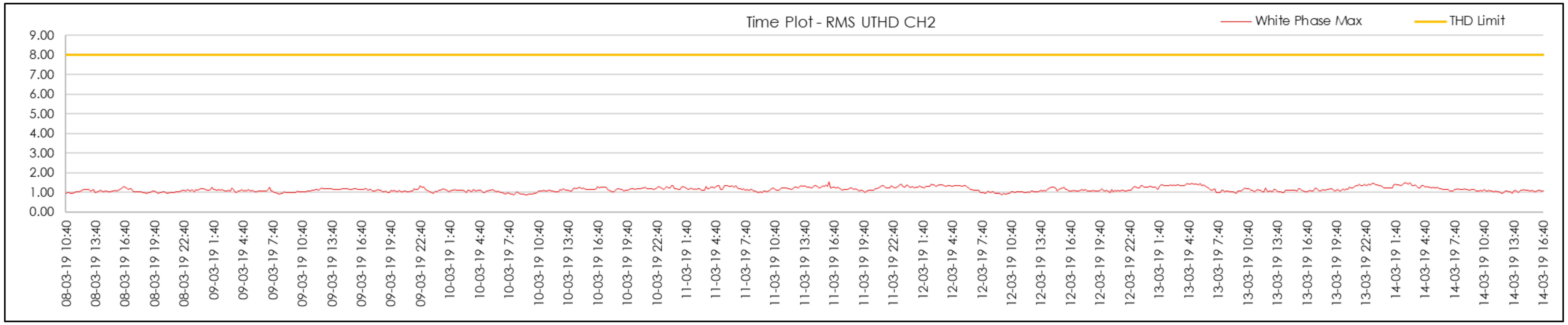

Figure 94 | TC3 Start U-THD measurements (White Phase)

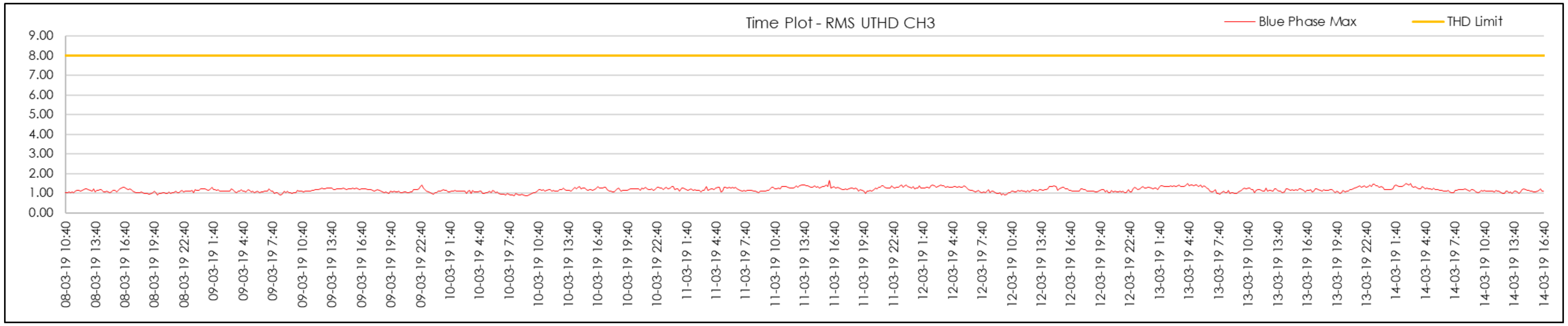

Figure 95 | TC3 Start U-THD measurements (Blue Phase)

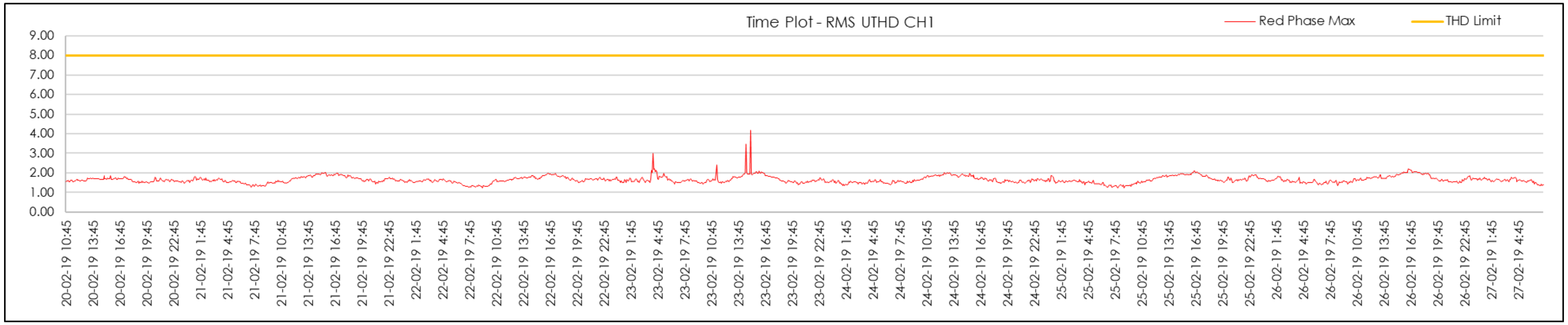

Figure 96 | TC3 End U-THD measurements (Red Phase)

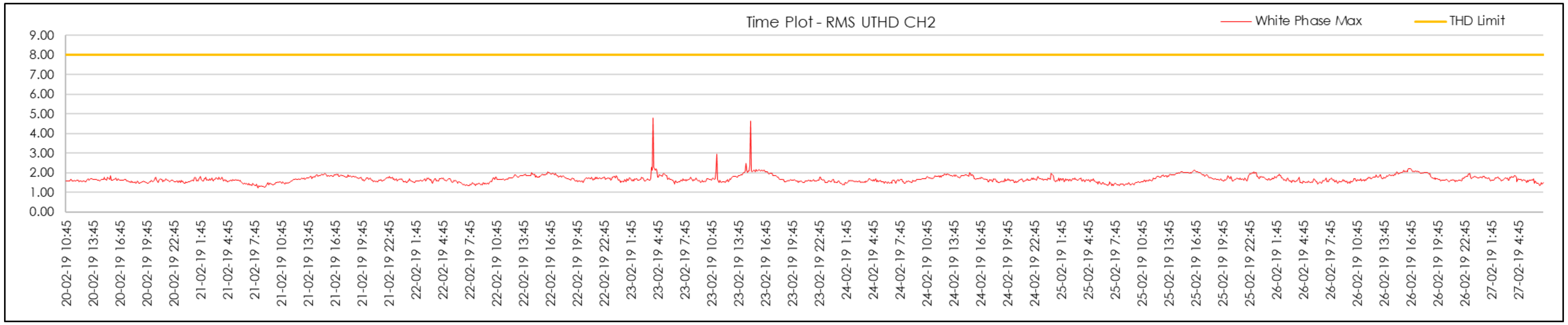

Figure 97 | TC3 End U-THD measurements (White Phase)

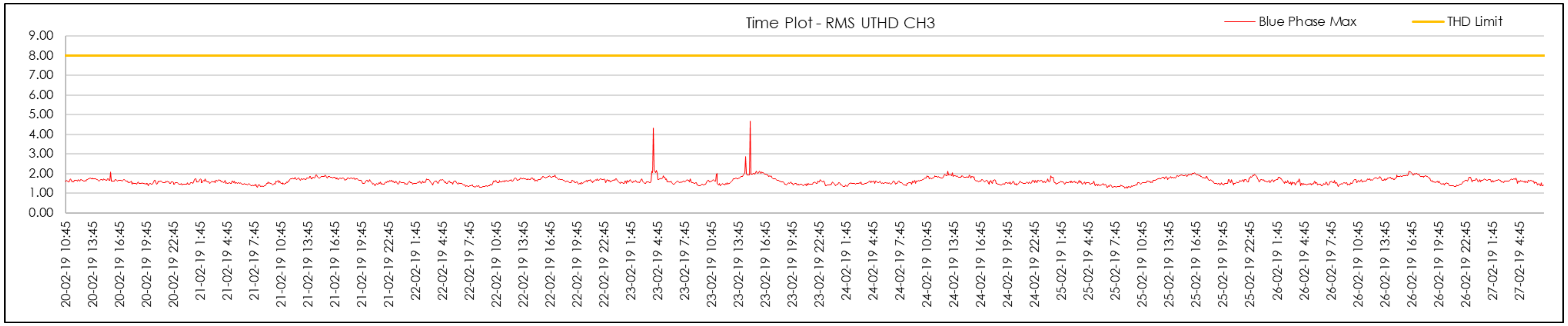

Figure 98 | TC3 End U-THD measurements (Blue Phase)

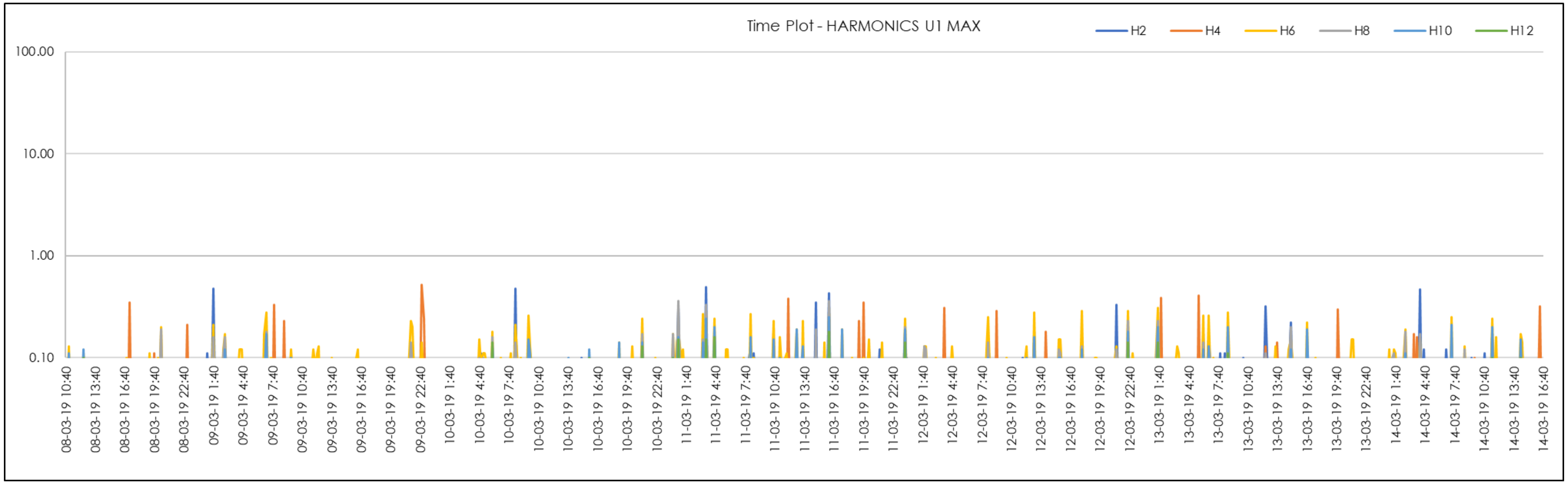

Figure 99 | TC3 Start Even 2nd-12th Harmonics (Red Phase)

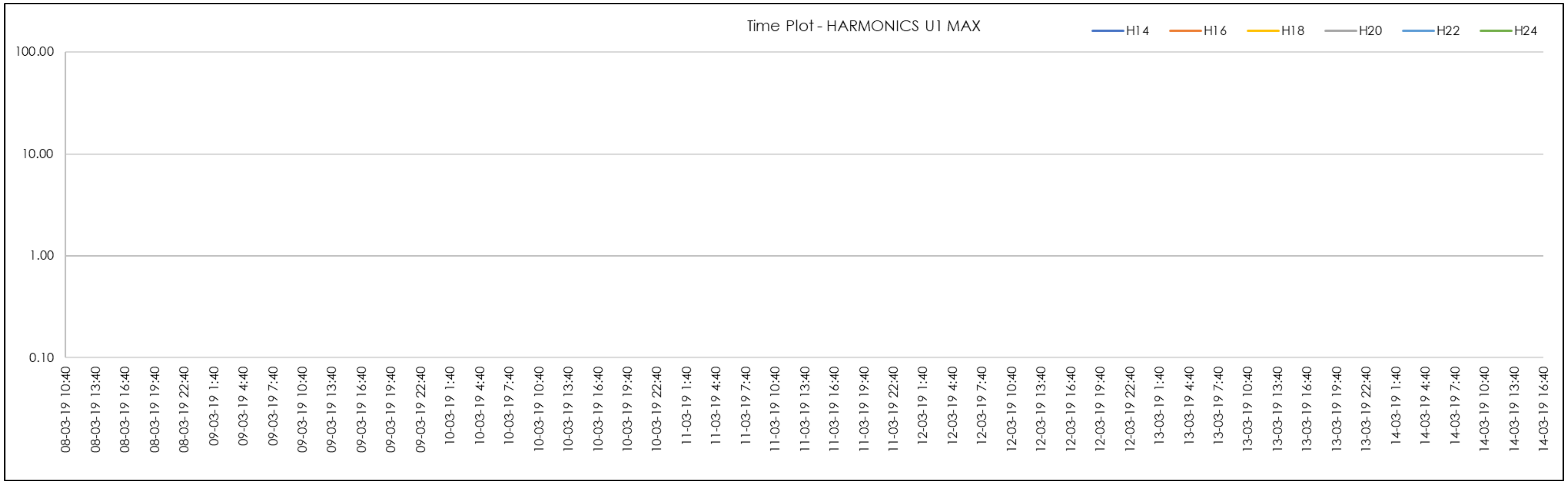

Figure 100 | TC3 Start Even 14th-24th Harmonics (Red Phase)

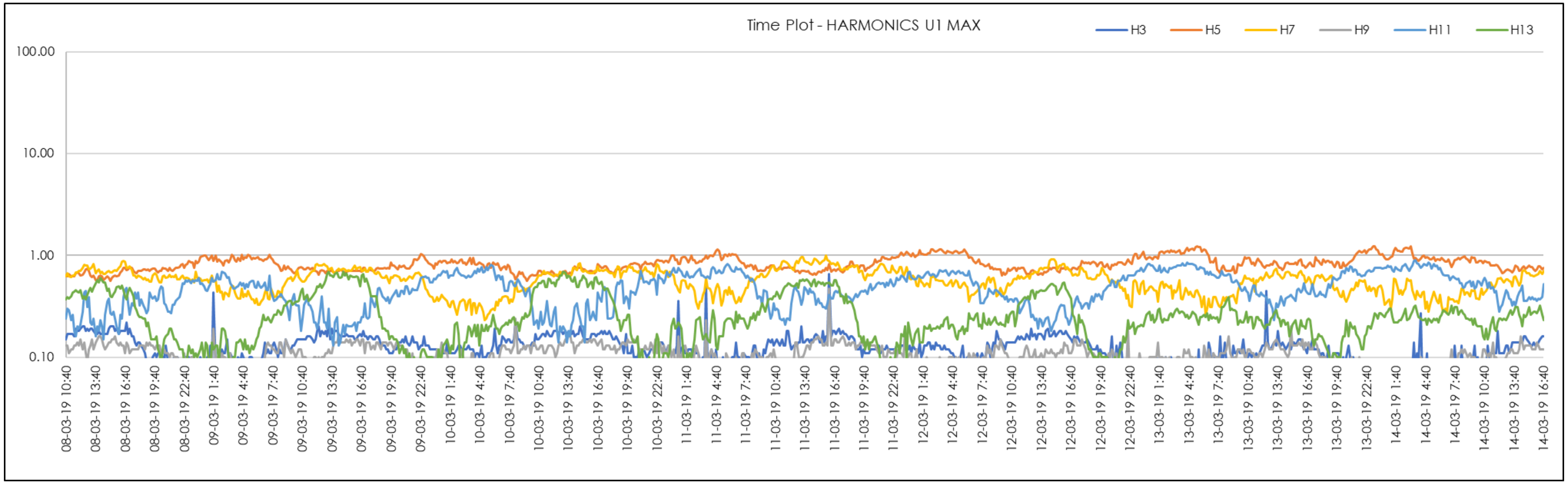

Figure 101 | TC3 Start Odd 3rd-13th Harmonics (Red Phase)

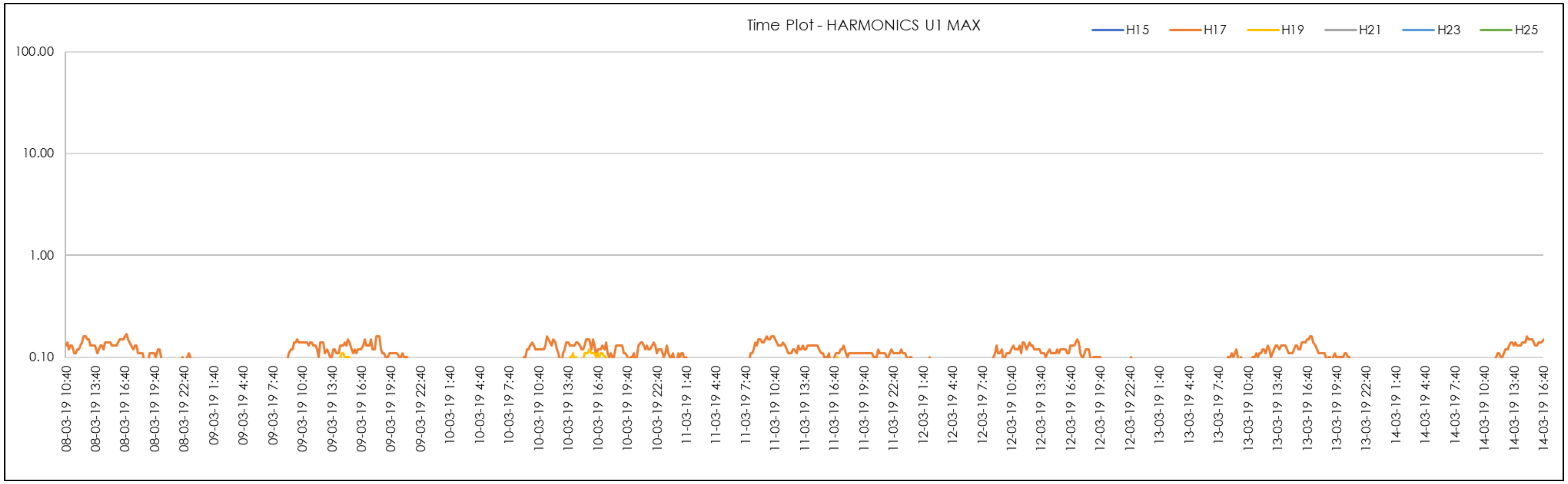

Figure 102 | TC3 Start Odd 15th-25th Harmonics (Red Phase)

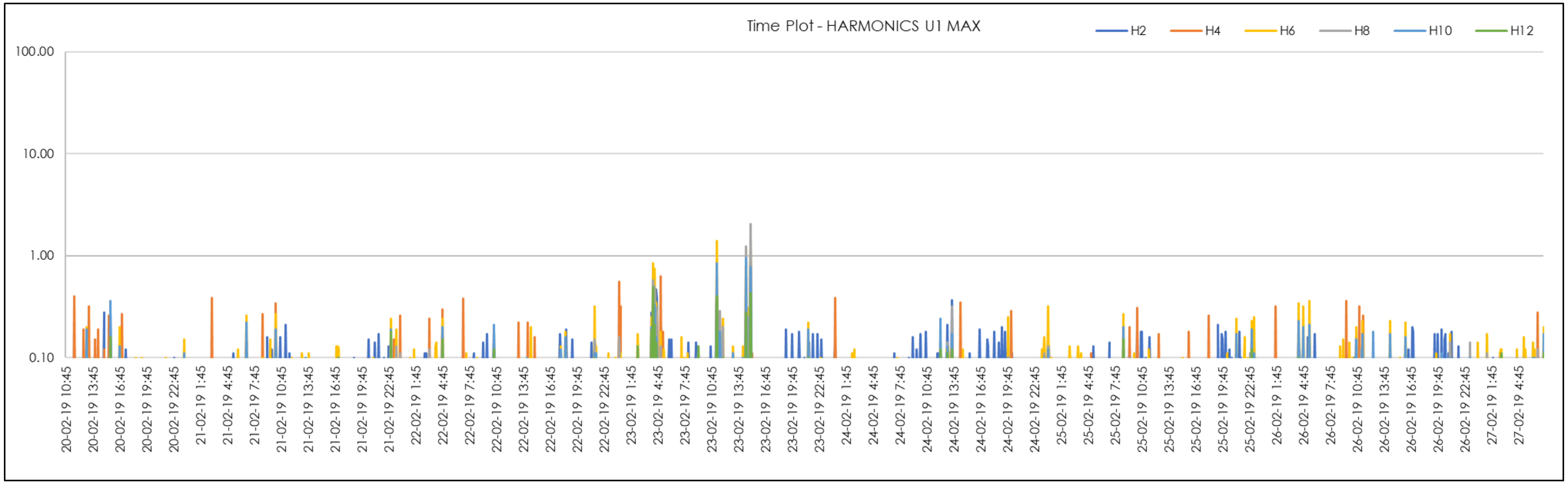

Figure 103 | TC3 End Even 2nd-12th Harmonics (Red Phase)

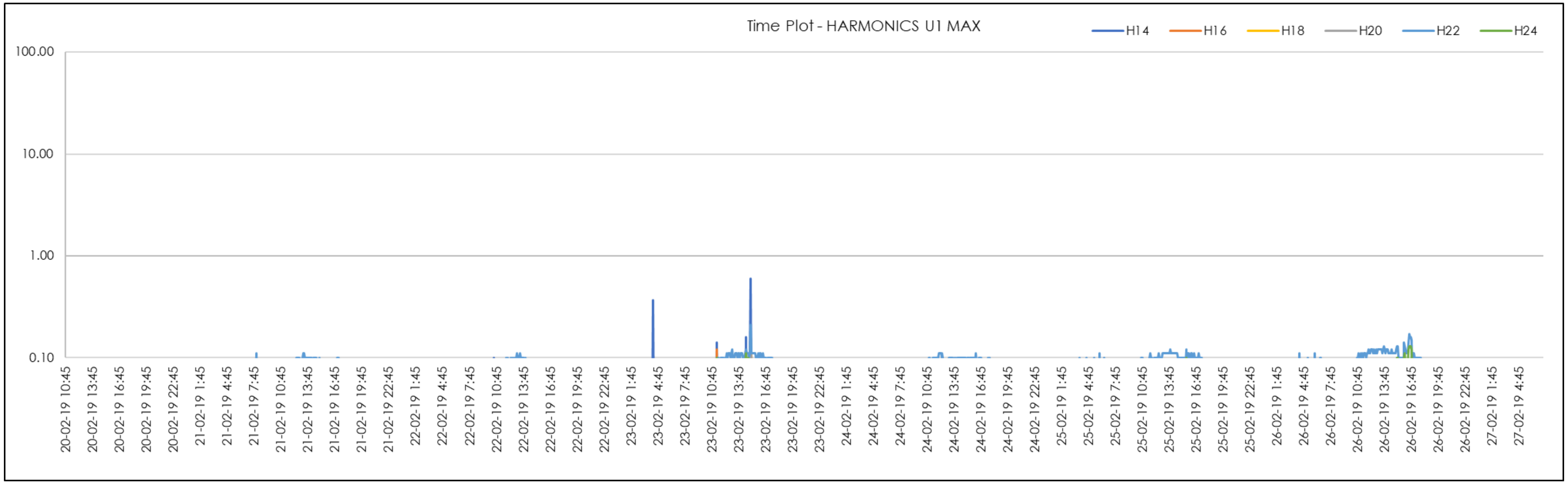

Figure 104 | TC3 End Even 14th-24th Harmonics (Red Phase)

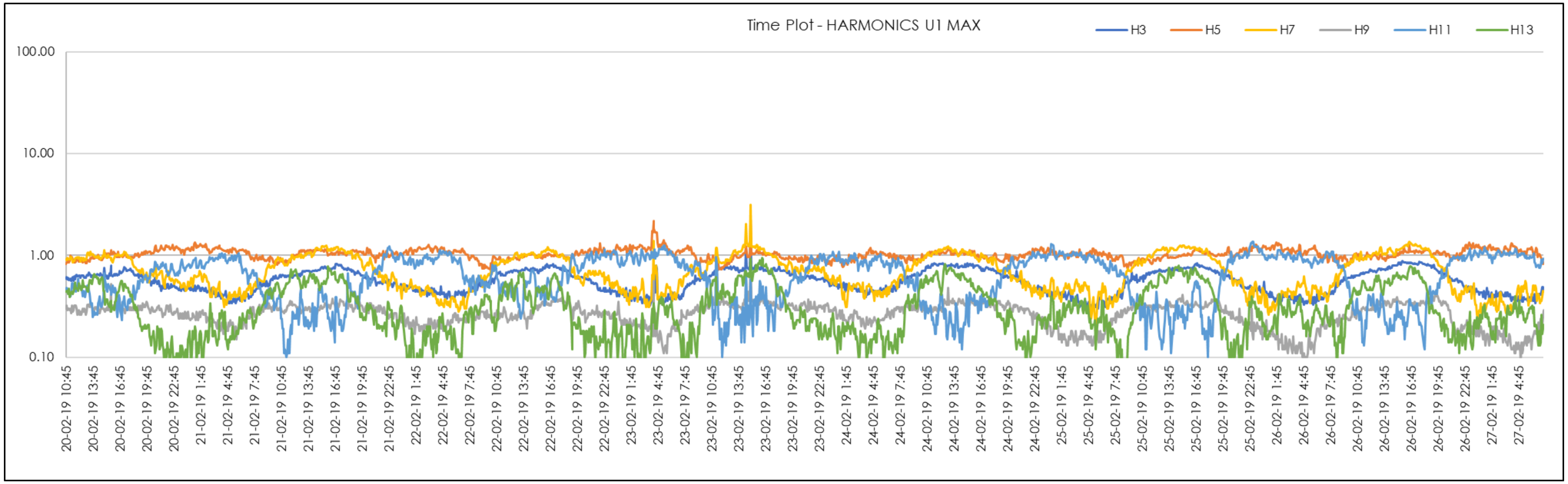

Figure 105 | TC3 End Odd 3rd-13th Harmonics (Red Phase)

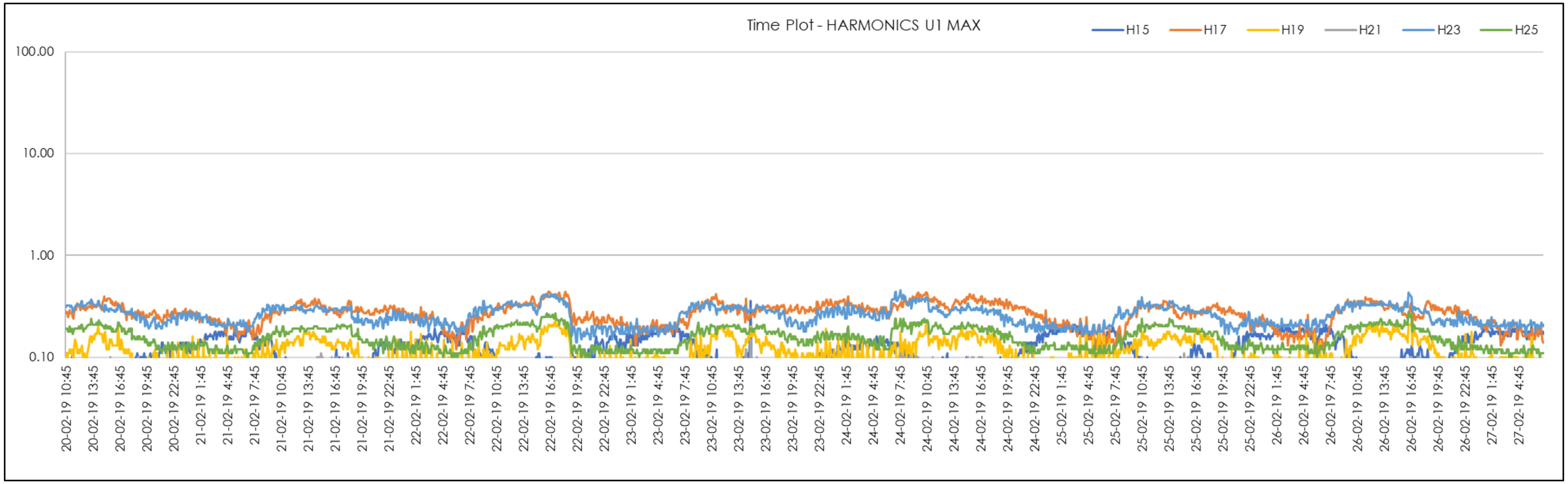

Figure 106 | TC3 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.4. FEEDER TC4 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

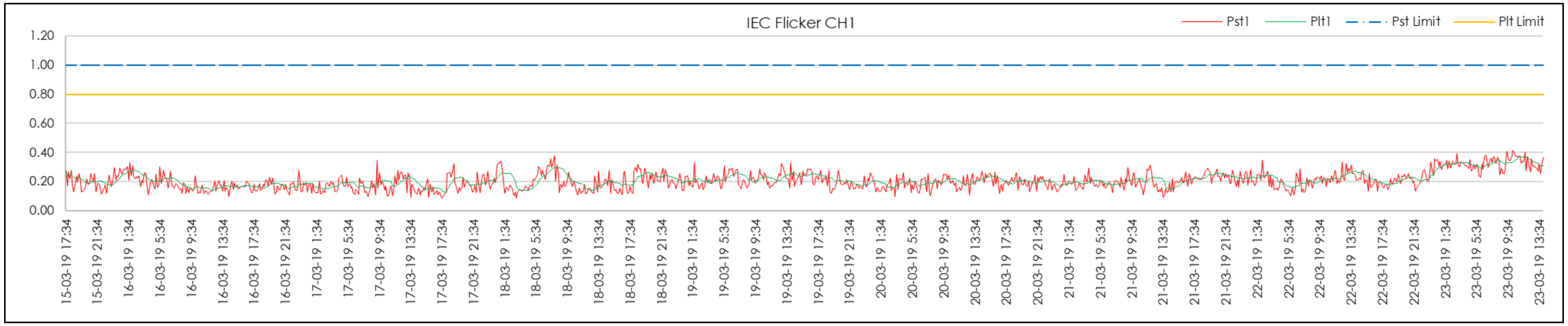

Figure 107 | TC4 Start Flicker measurements (Red Phase)

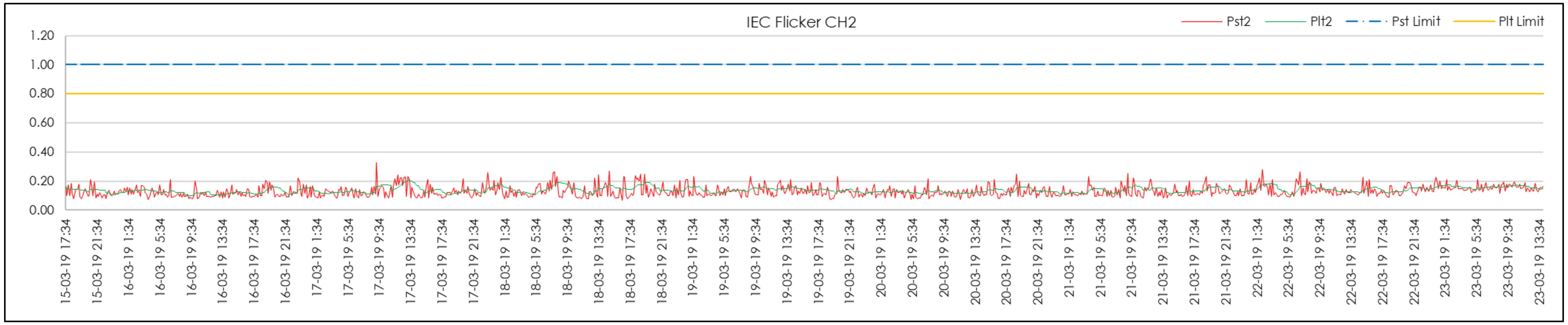

Figure 108 | TC4 Start Flicker measurements (White Phase)

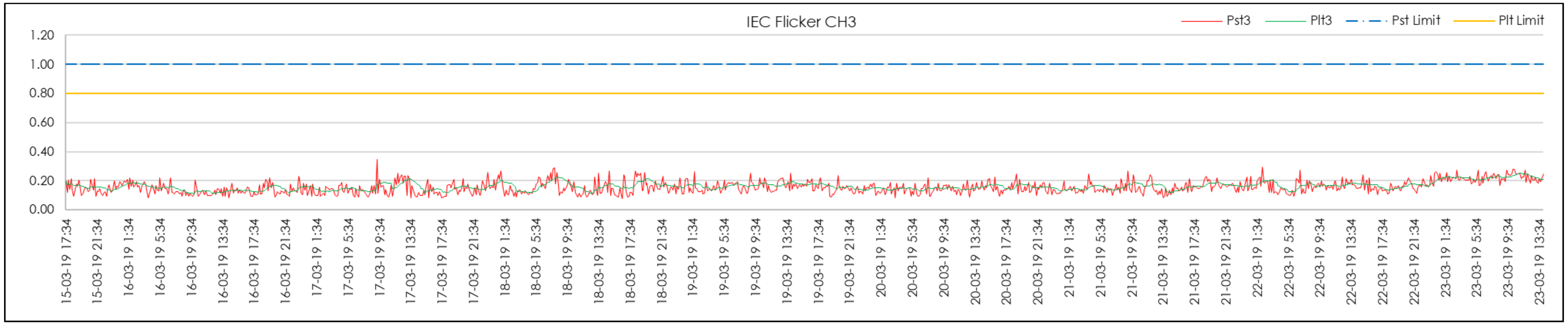

Figure 109 | TC4 Start Flicker measurements (Blue Phase)

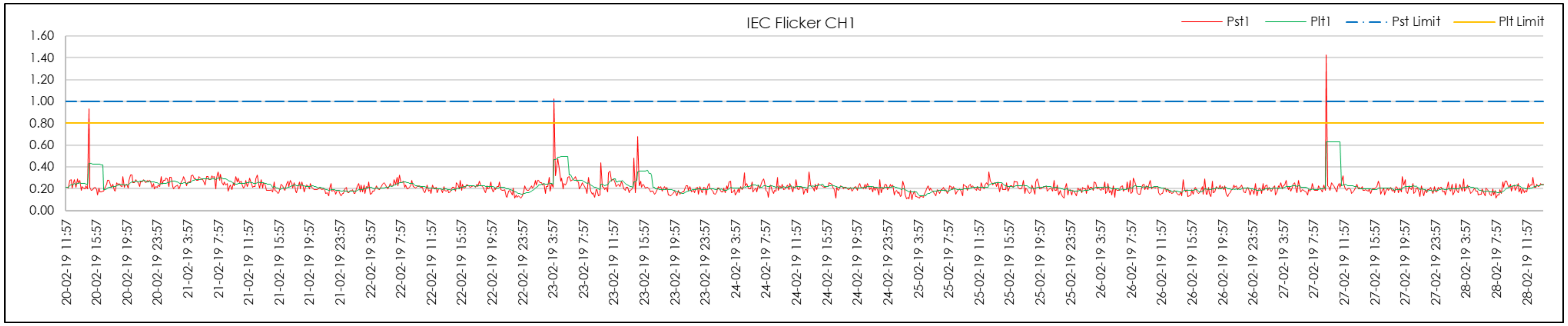

Figure 110 | TC4 End Flicker measurements (Red Phase)

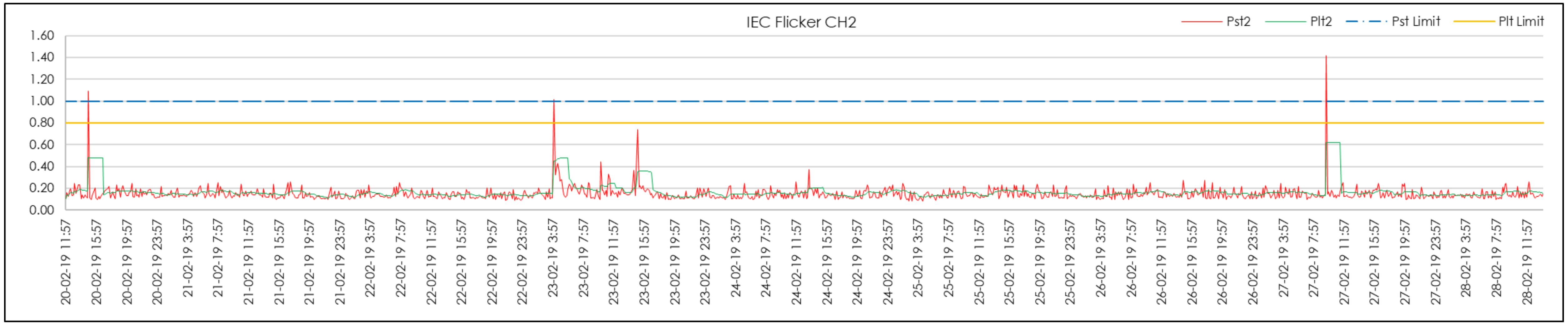

Figure 111 | TC4 End Flicker measurements (White Phase)

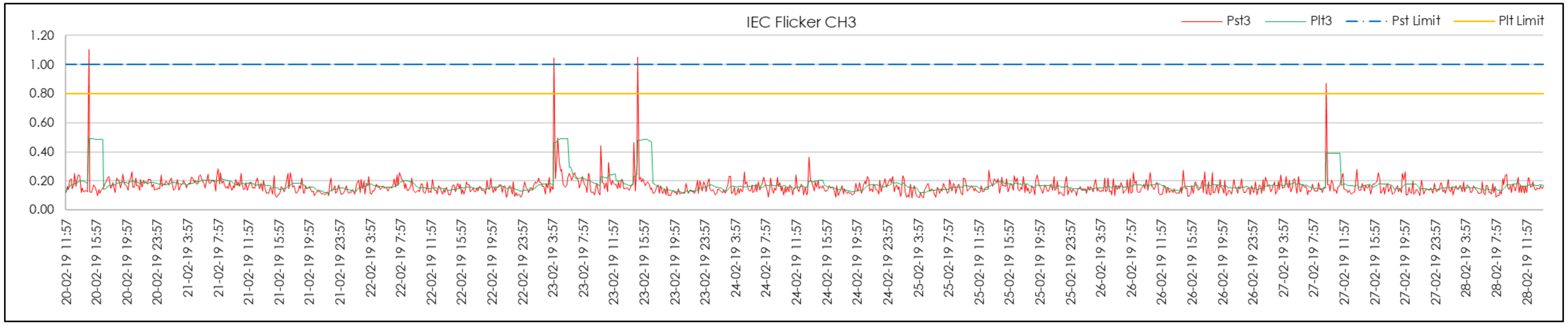

Figure 112 | TC4 End Flicker measurements (Blue Phase)

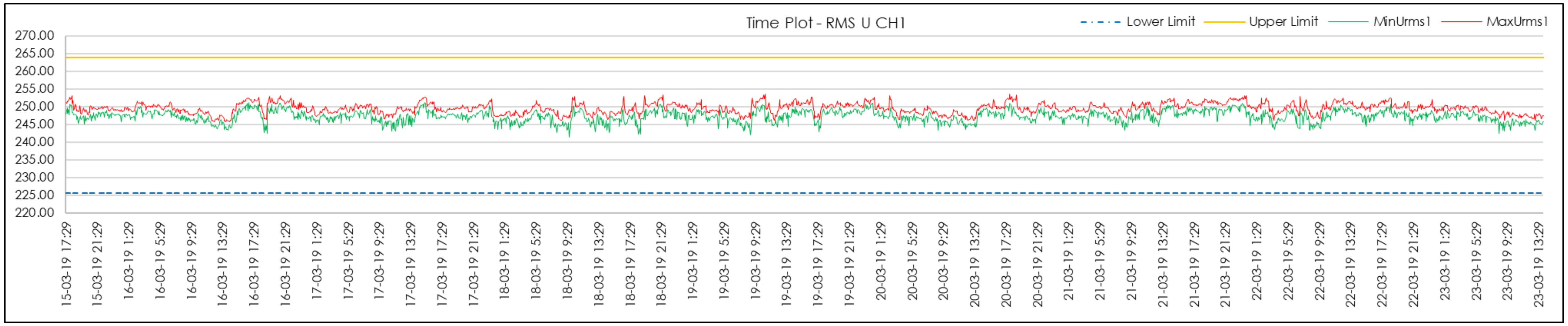

Figure 113 | TC4 Start Voltage measurements (Red Phase)

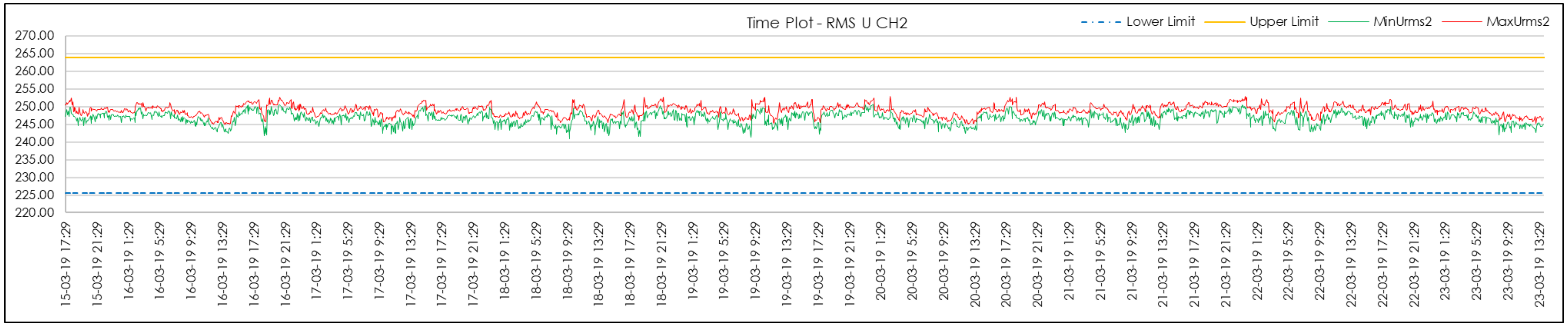

Figure 114 | TC4 Start Voltage measurements (White Phase)

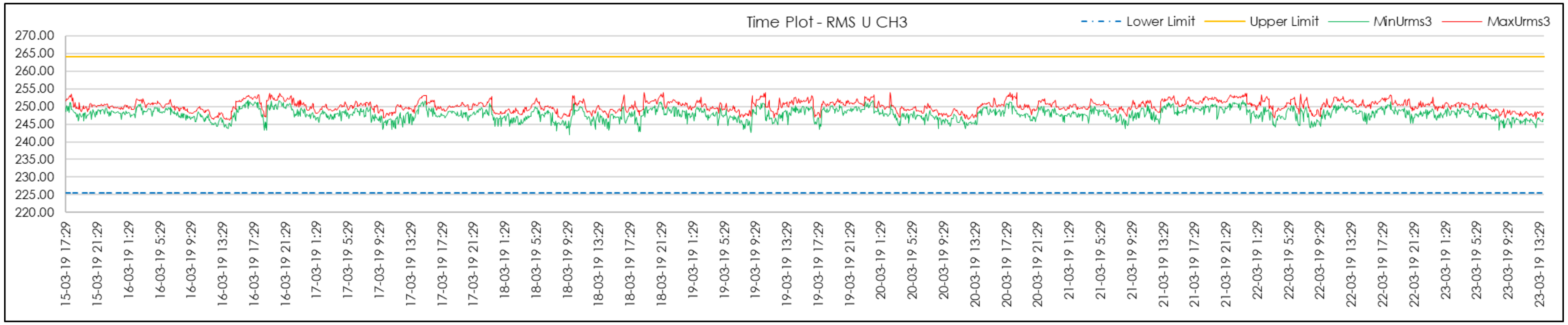

Figure 115 | TC4 Start Voltage measurements (Blue Phase)

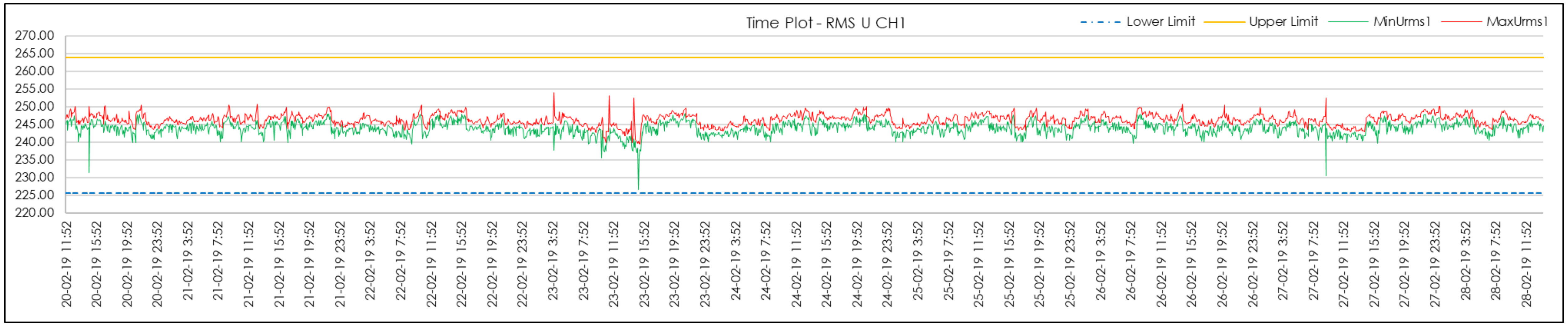

Figure 116 | TC4 End Voltage measurements (Red Phase)

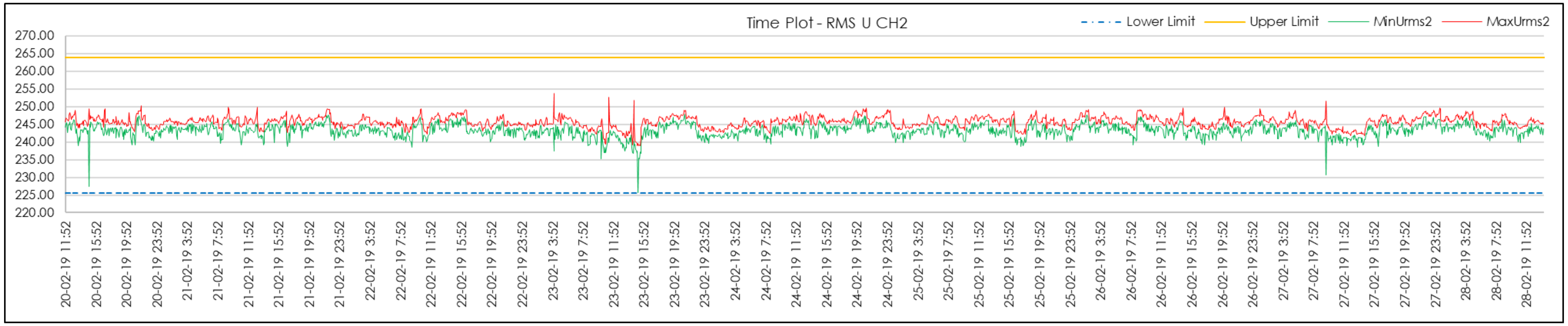

Figure 117 | TC4 End Voltage measurements (White Phase)

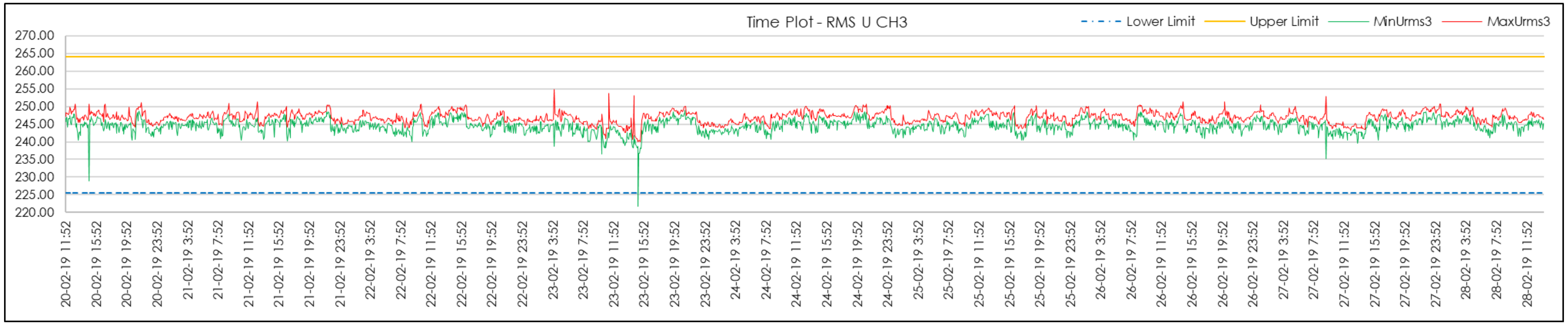

Figure 118 | TC4 End Voltage measurements (Blue Phase)

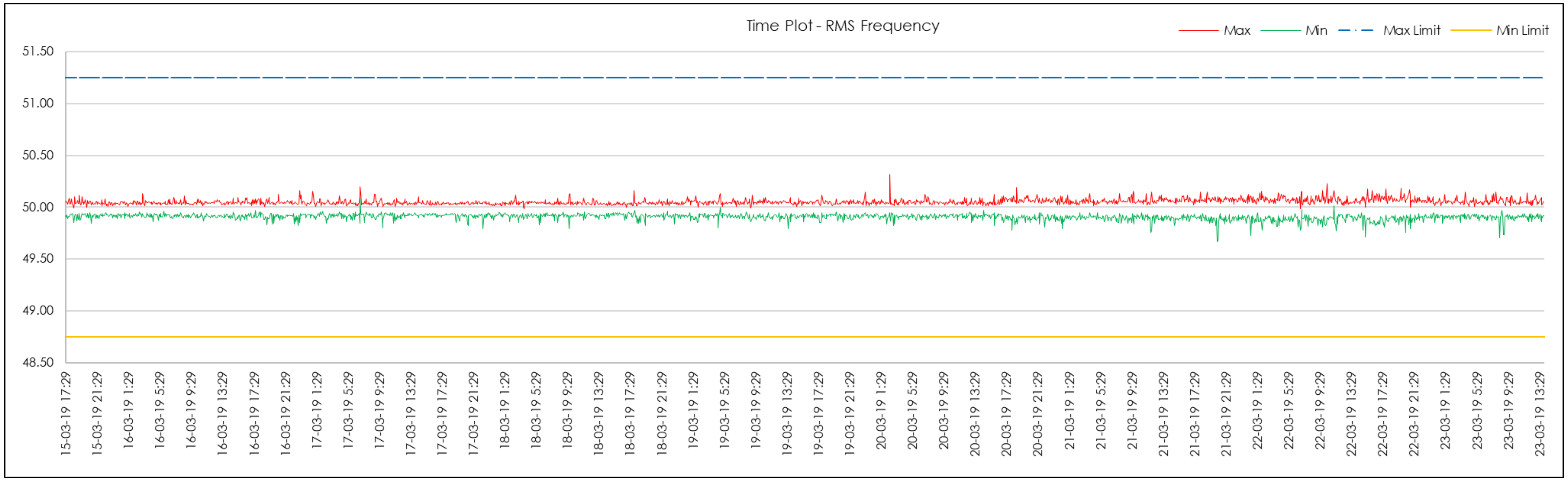

Figure 119 | TC4 Start Frequency measurements

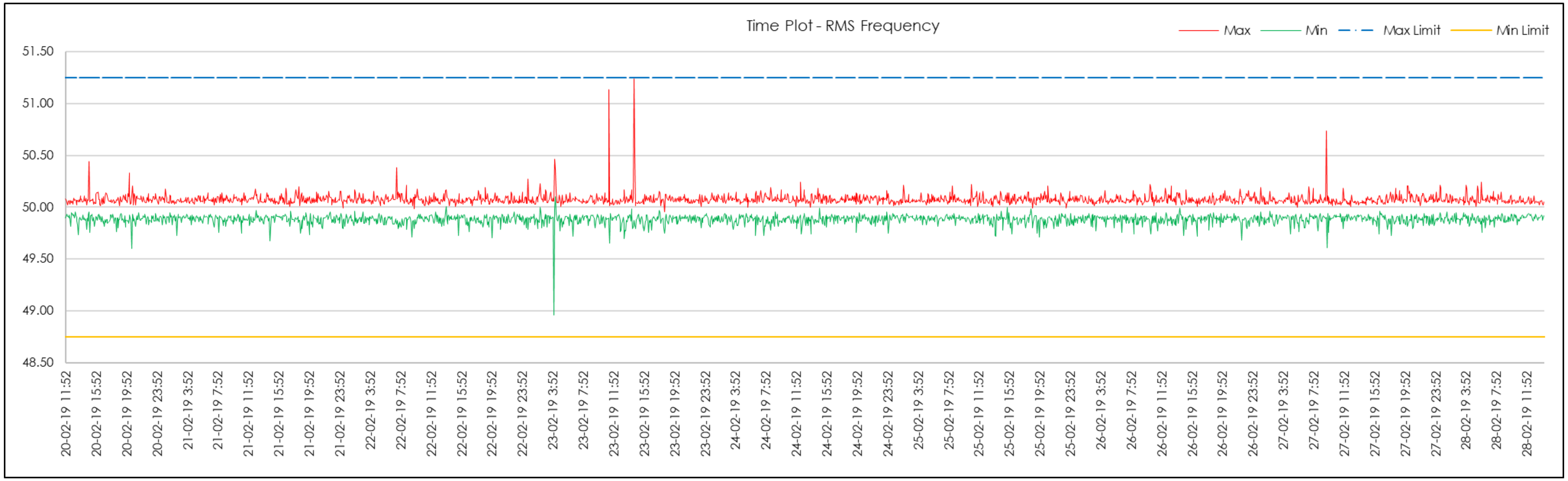

Figure 120 | TC4 End Frequency measurements

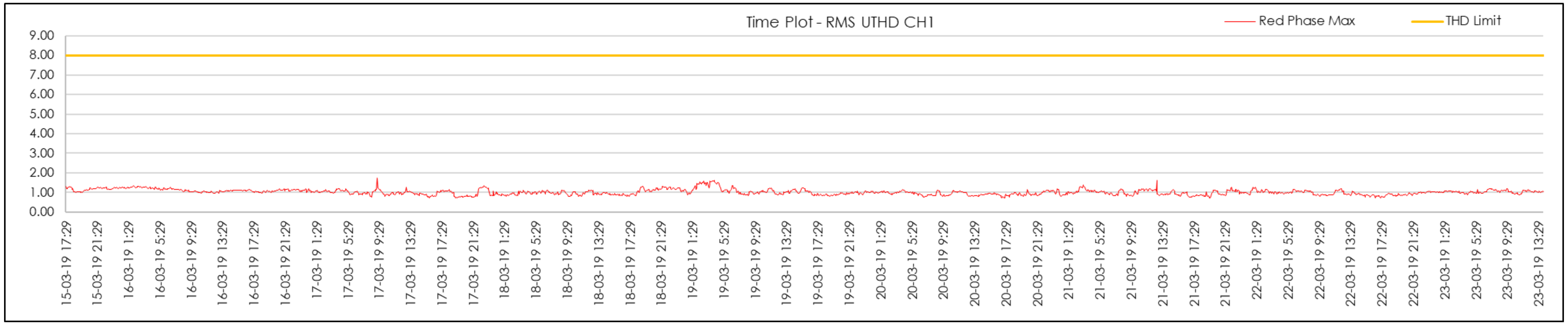

Figure 121 | TC4 Start U-THD measurements (Red Phase)

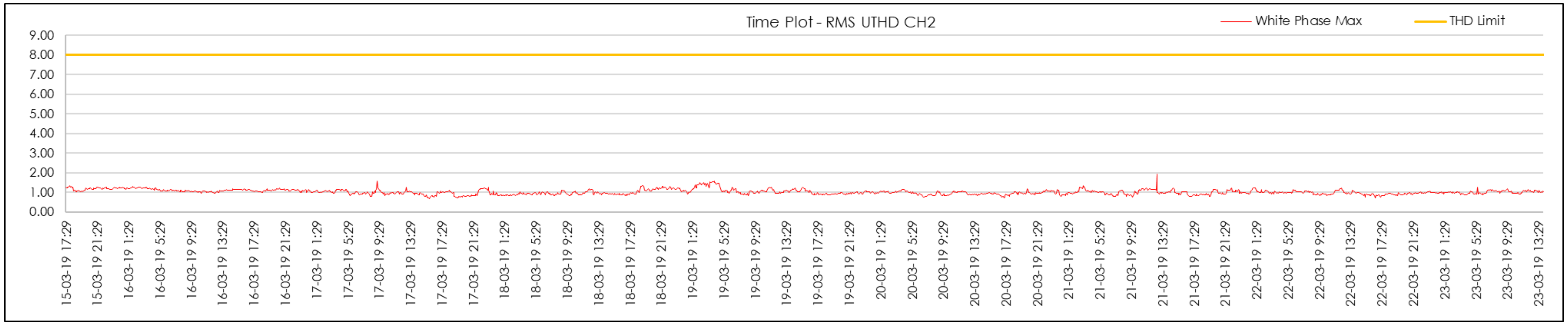

Figure 122 | TC4 Start U-THD measurements (White Phase)

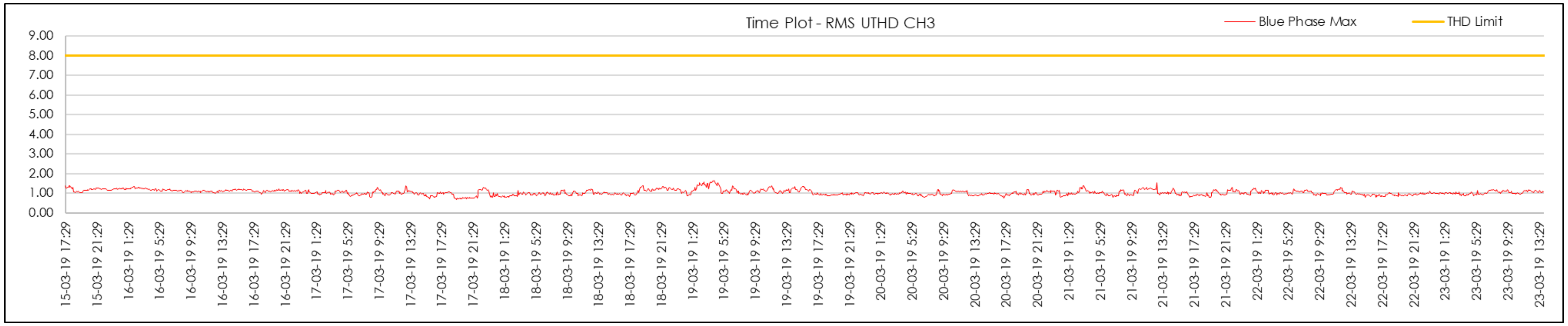

Figure 123 | TC4 Start U-THD measurements (Blue Phase)

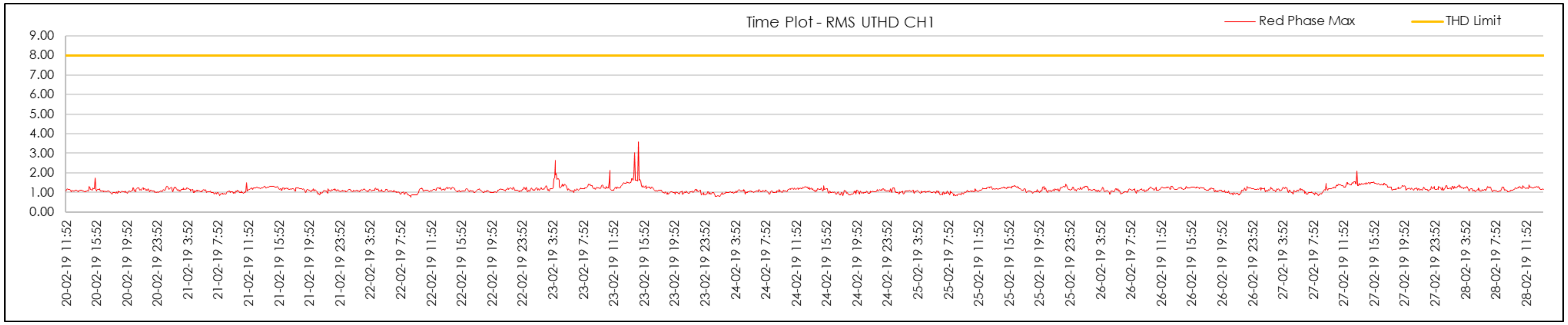

Figure 124 | TC4 End U-THD measurements (Red Phase)

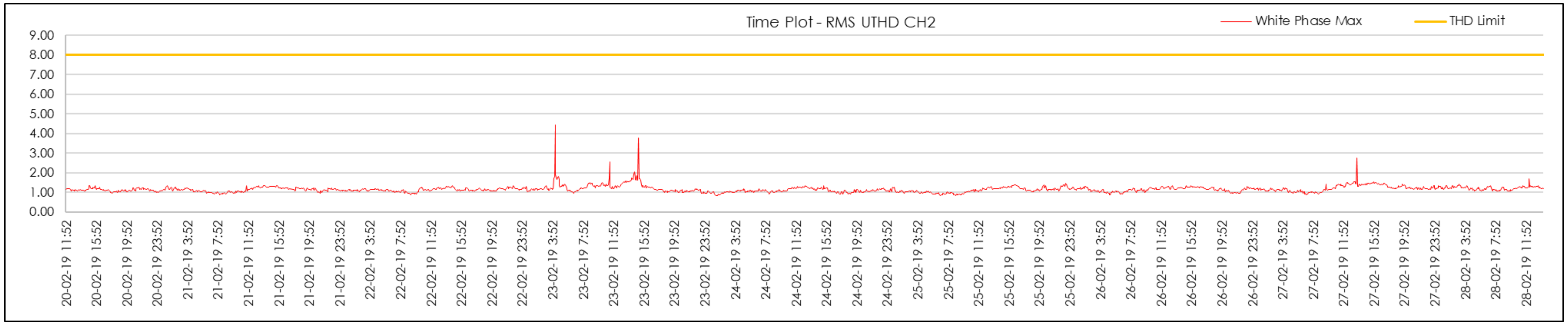

Figure 125 | TC4 End U-THD measurements (White Phase)

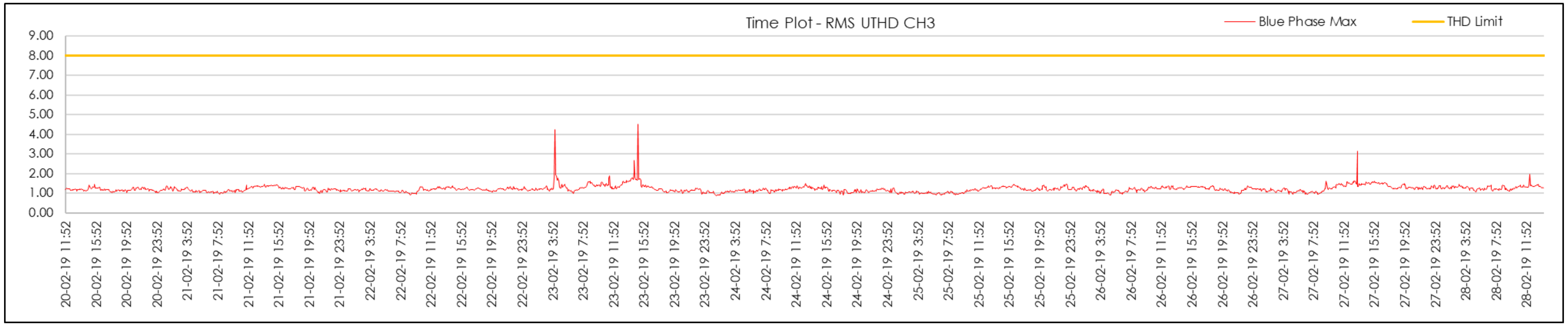

Figure 126 | TC4 End U-THD measurements (Blue Phase)

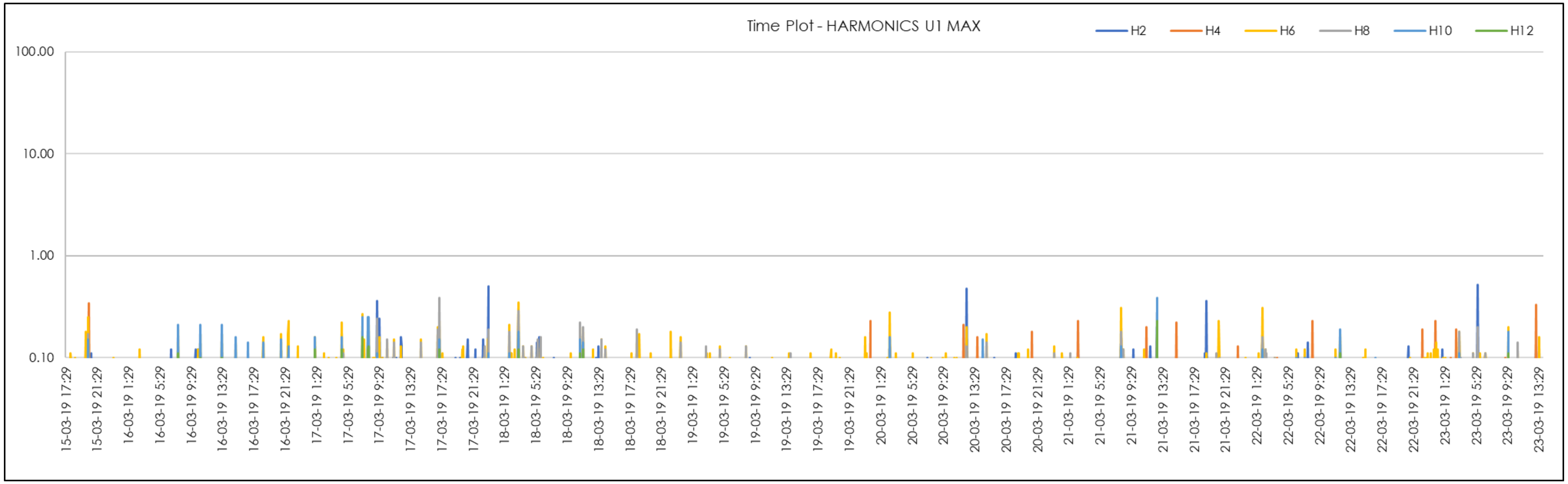

Figure 127 | TC4 Start Even 2nd-12th Harmonics (Red Phase)

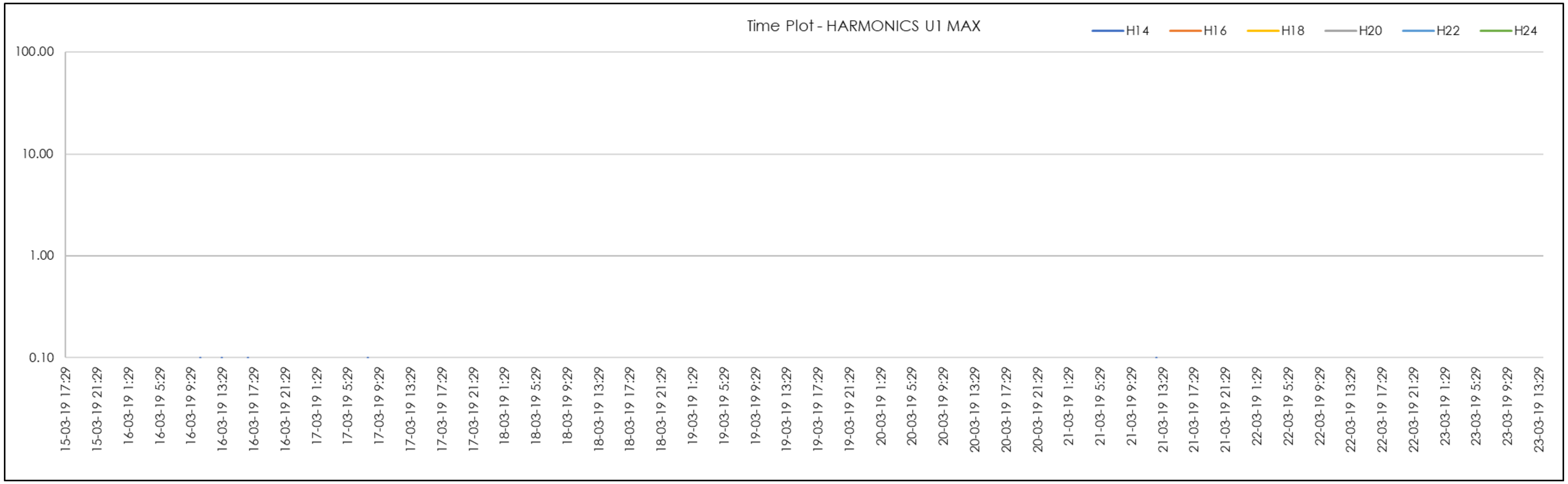

Figure 128 | TC4 Start Even 14th-24th Harmonics (Red Phase)

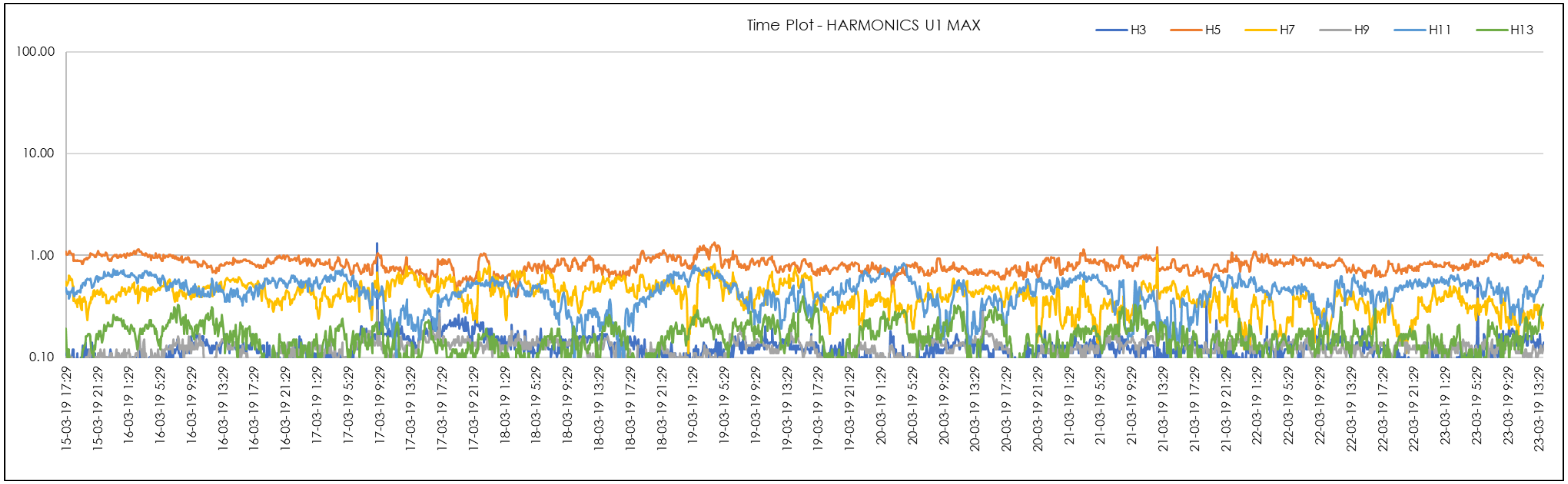

Figure 129 | TC4 Start Odd 3rd-13th Harmonics (Red Phase)

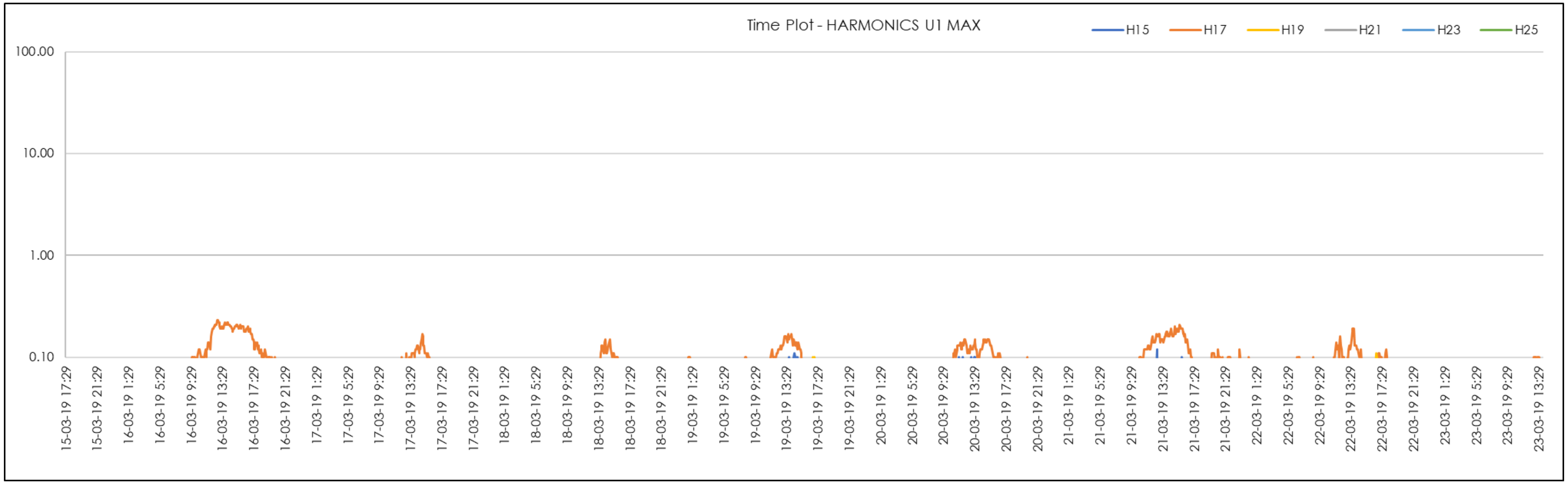

Figure 130 | TC4 Start Odd 15th-25th Harmonics (Red Phase)

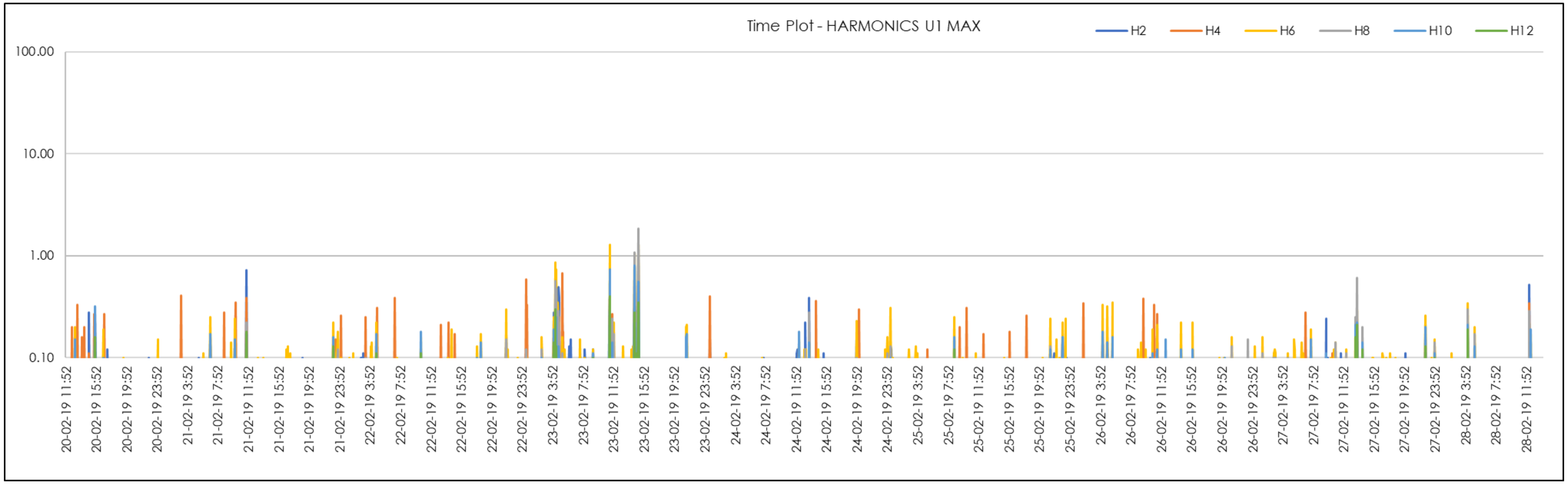

Figure 131 | TC4 End Even 2nd-12th Harmonics (Red Phase)

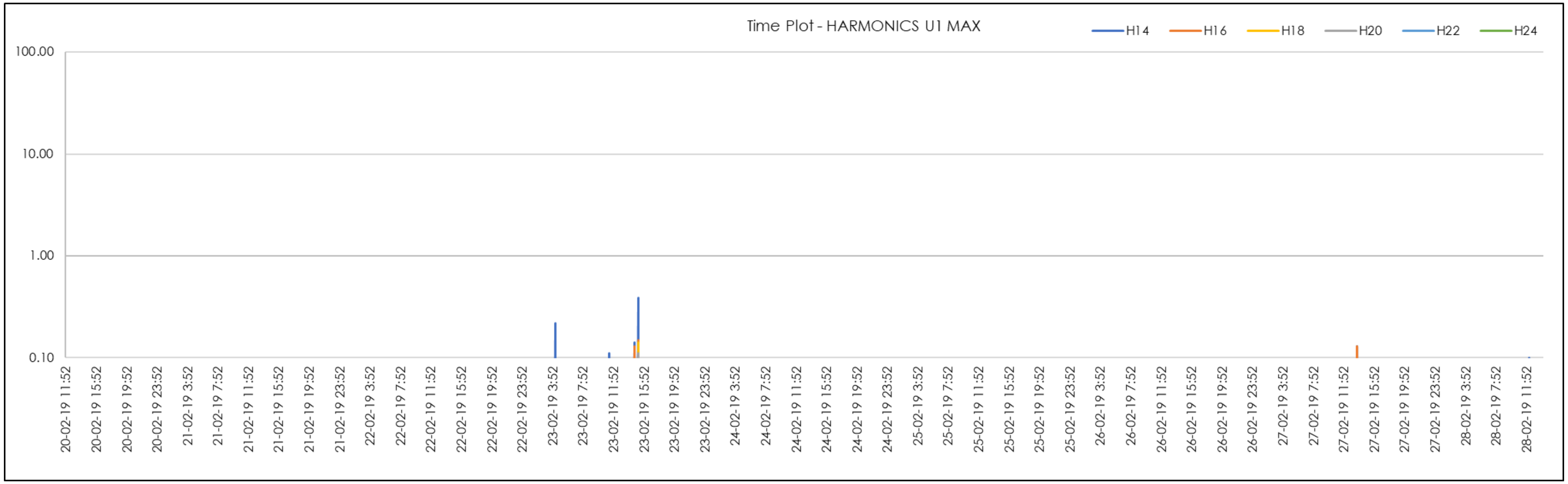

Figure 132 | TC4 End Even 14th-24th Harmonics (Red Phase)

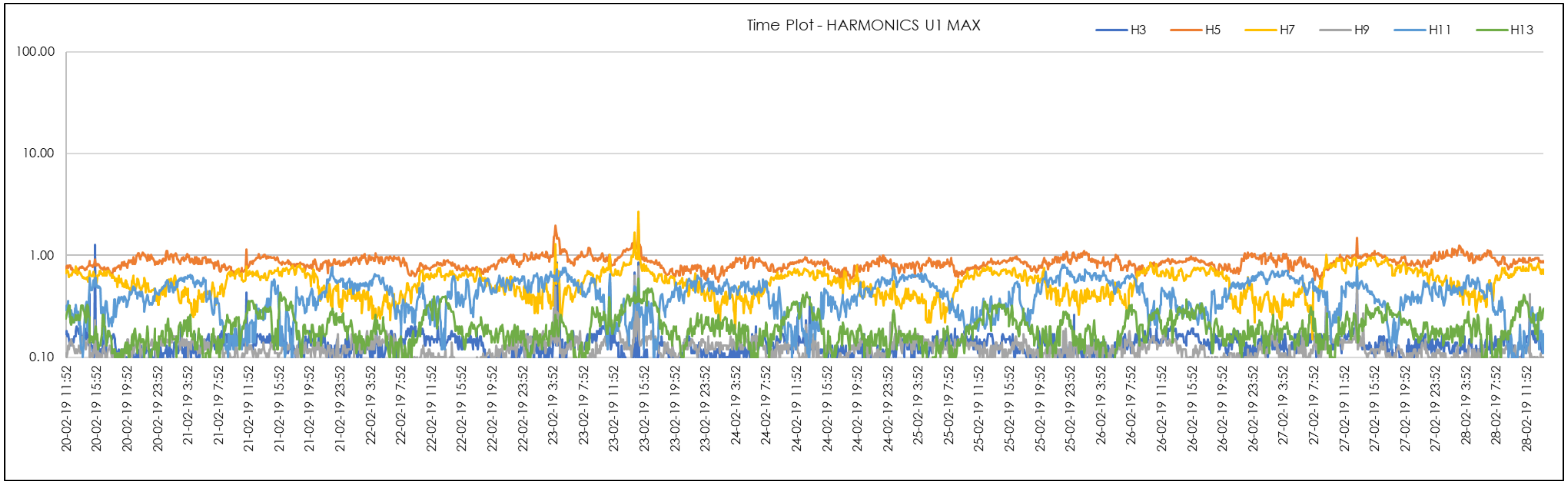

Figure 133 | TC4 End Odd 3rd-13th Harmonics (Red Phase)

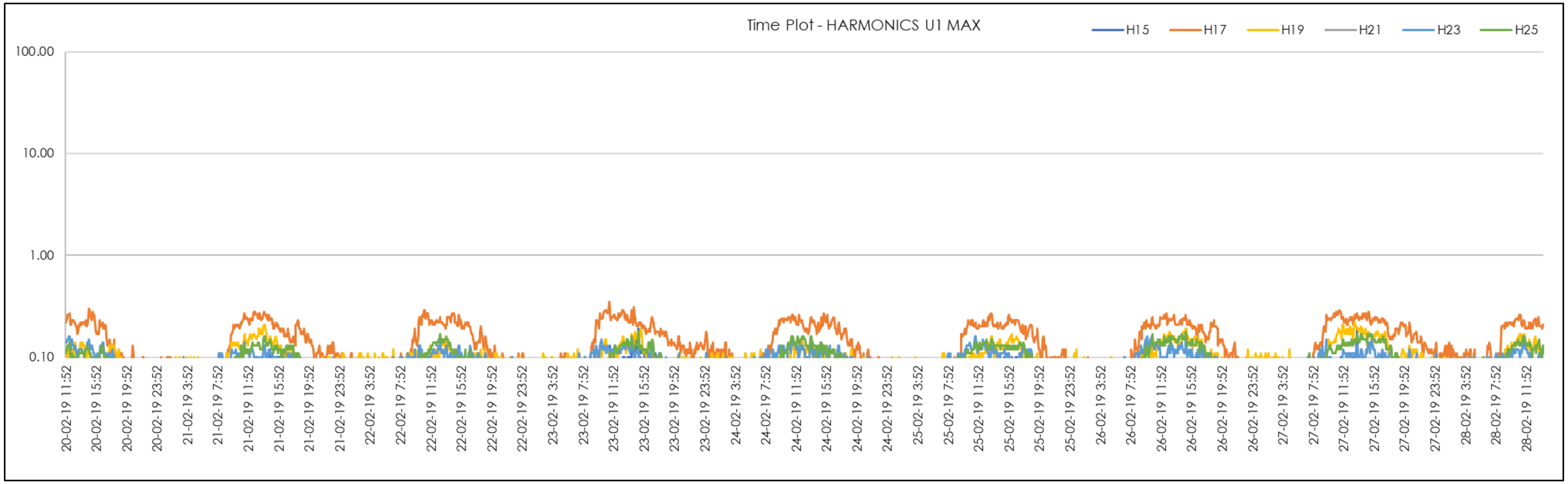

Figure 134 | TC4 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.5. FEEDER STS1 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

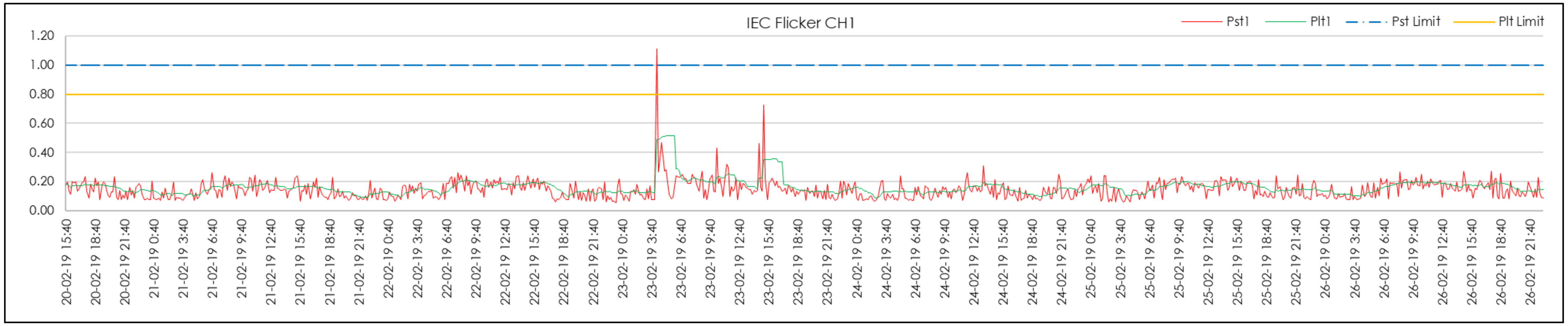

Figure 135 | STS1 Start Flicker measurements (Red Phase)

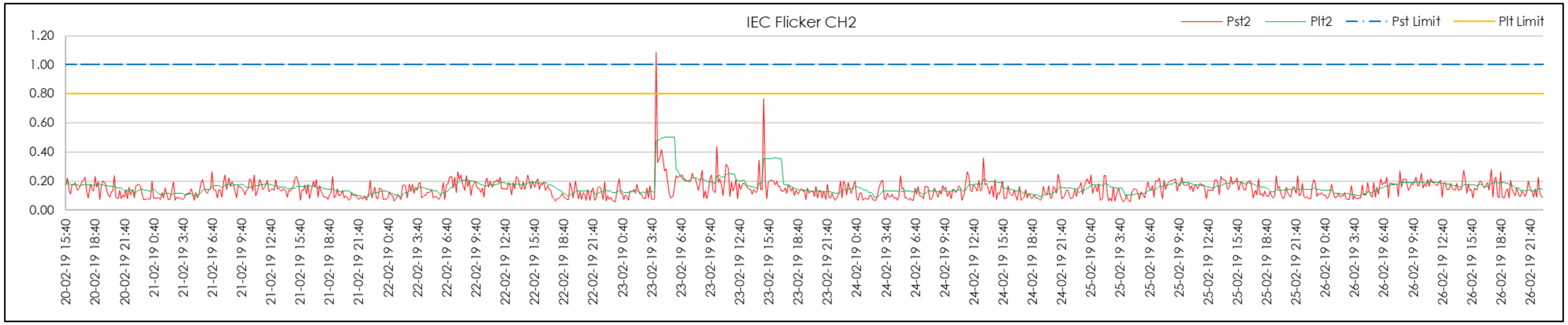

Figure 136 | STS1 Start Flicker measurements (White Phase)

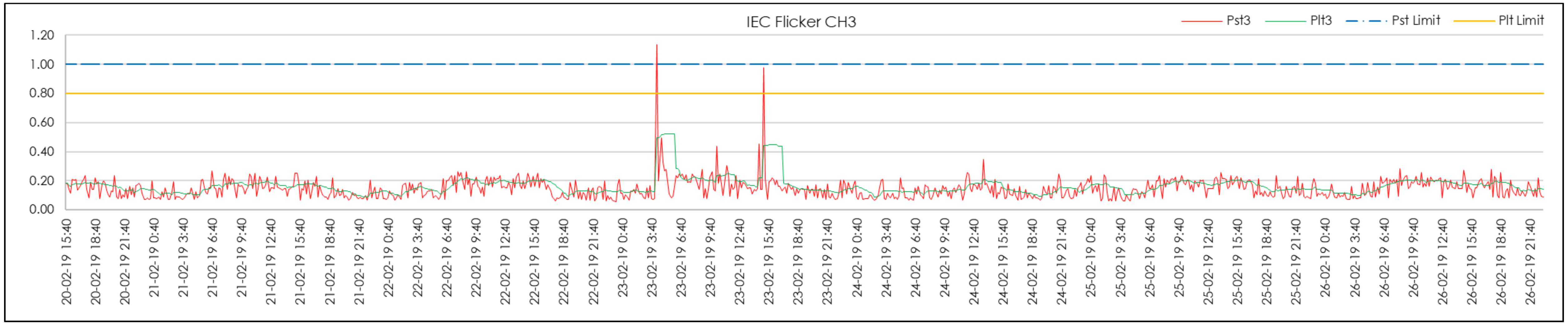

Figure 137 | STS1 Start Flicker measurements (Blue Phase)

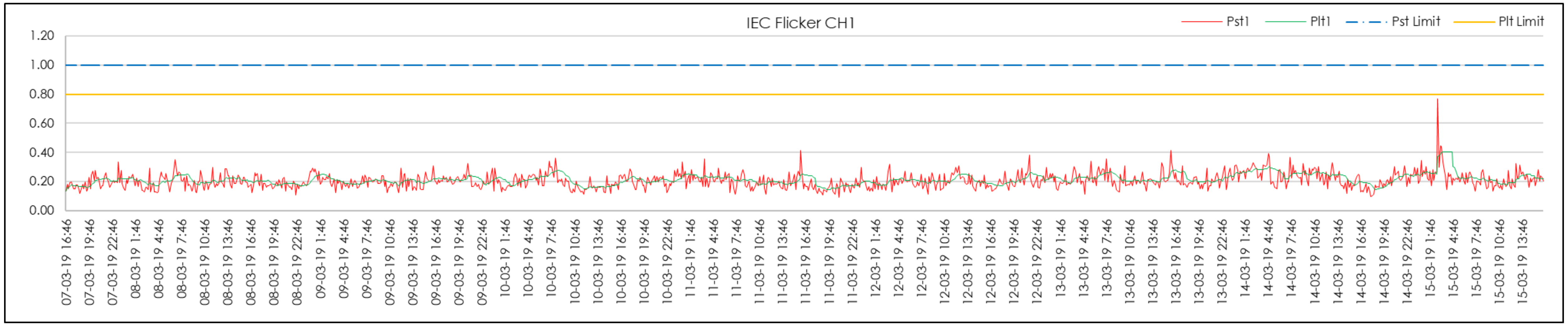

Figure 138 | STS1 End Flicker measurements (Red Phase)

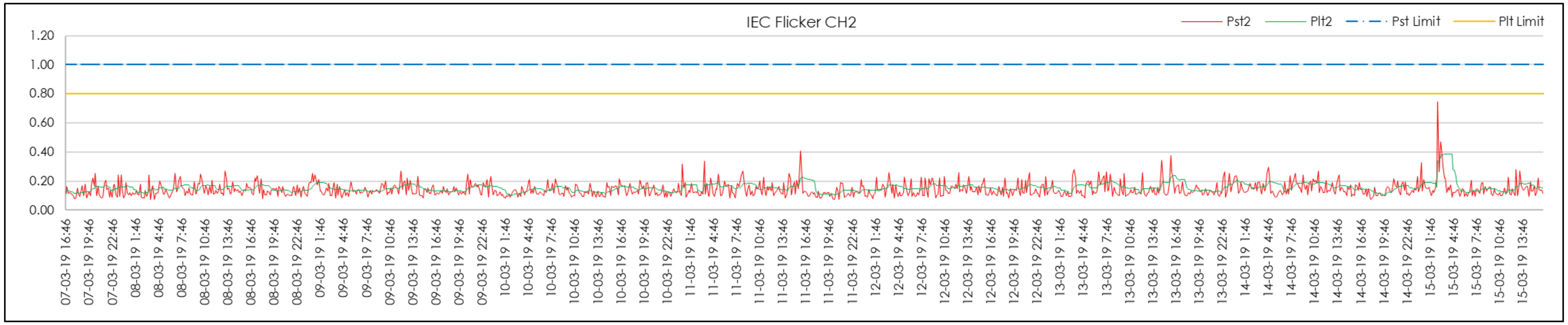

Figure 139 | STS1 End Flicker measurements (White Phase)

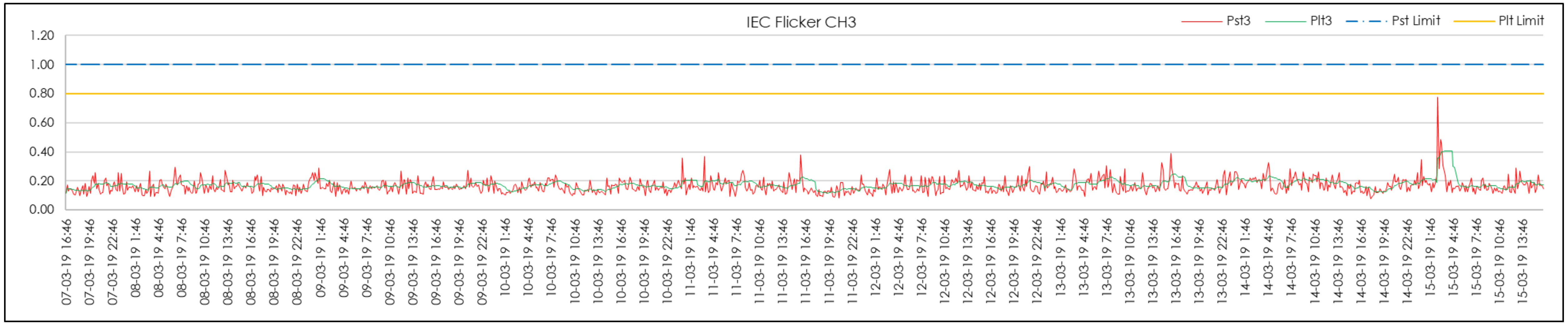

Figure 140 | STS1 End Flicker measurements (Blue Phase)

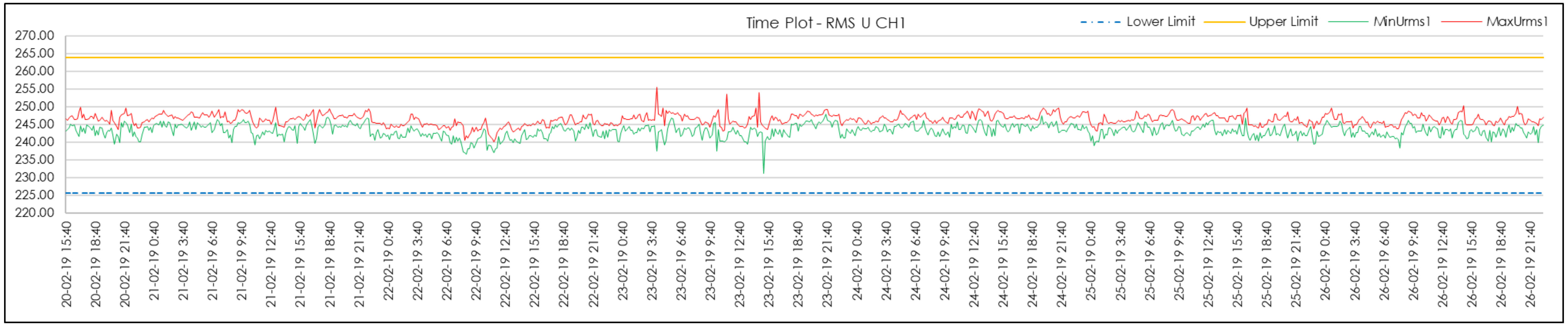

Figure 141 | STS1 Start Voltage measurements (Red Phase)

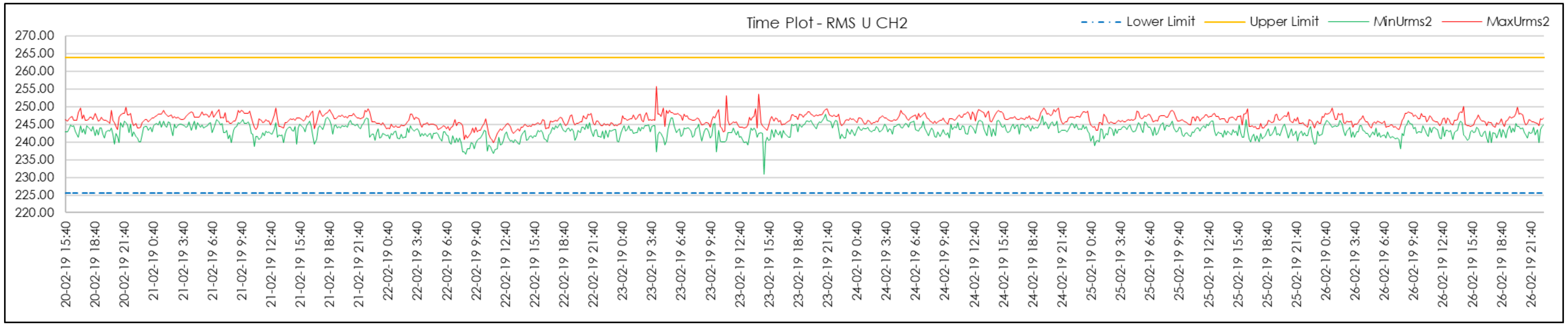

Figure 142 | STS1 Start Voltage measurements (White Phase)

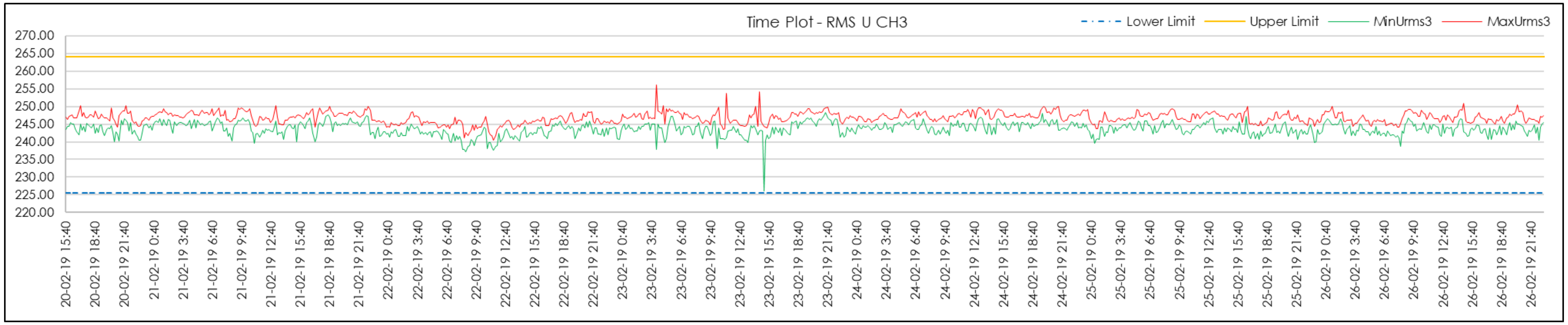

Figure 143 | STS1 Start Voltage measurements (Blue Phase)

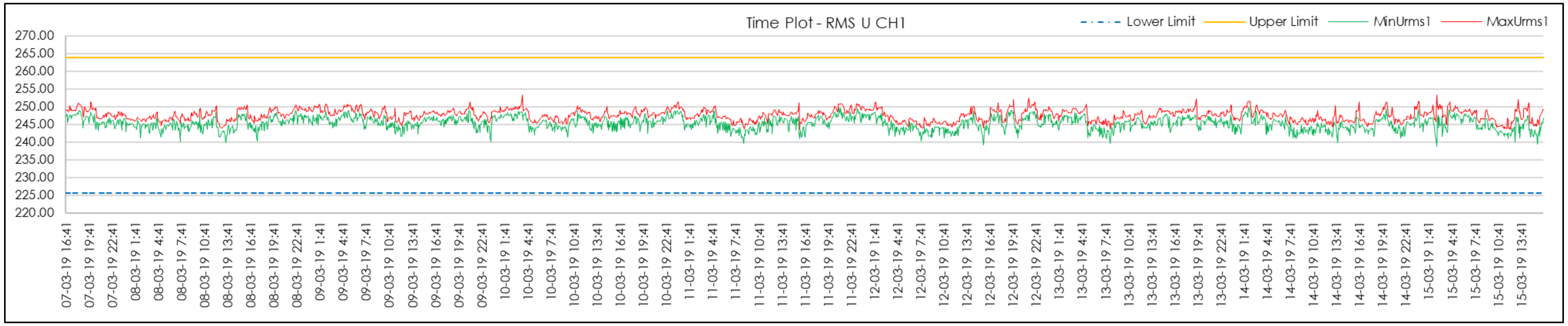

Figure 144 | STS1 End Voltage measurements (Red Phase)

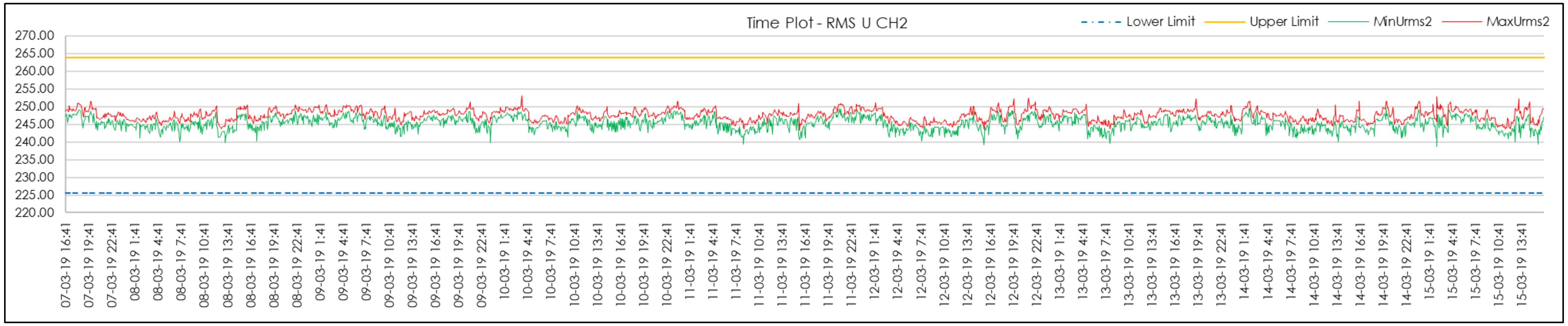

Figure 145 | STS1 End Voltage measurements (White Phase)

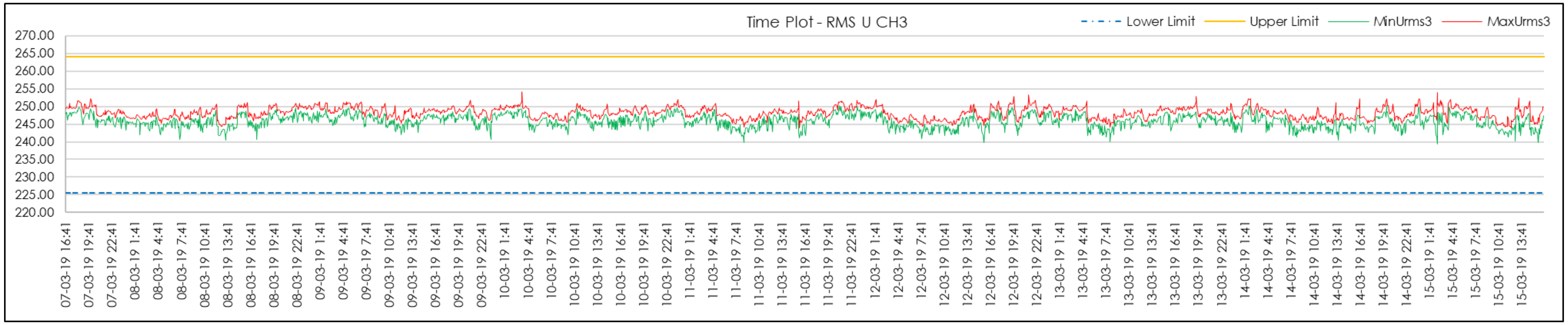

Figure 146 | STS1 End Voltage measurements (Blue Phase)

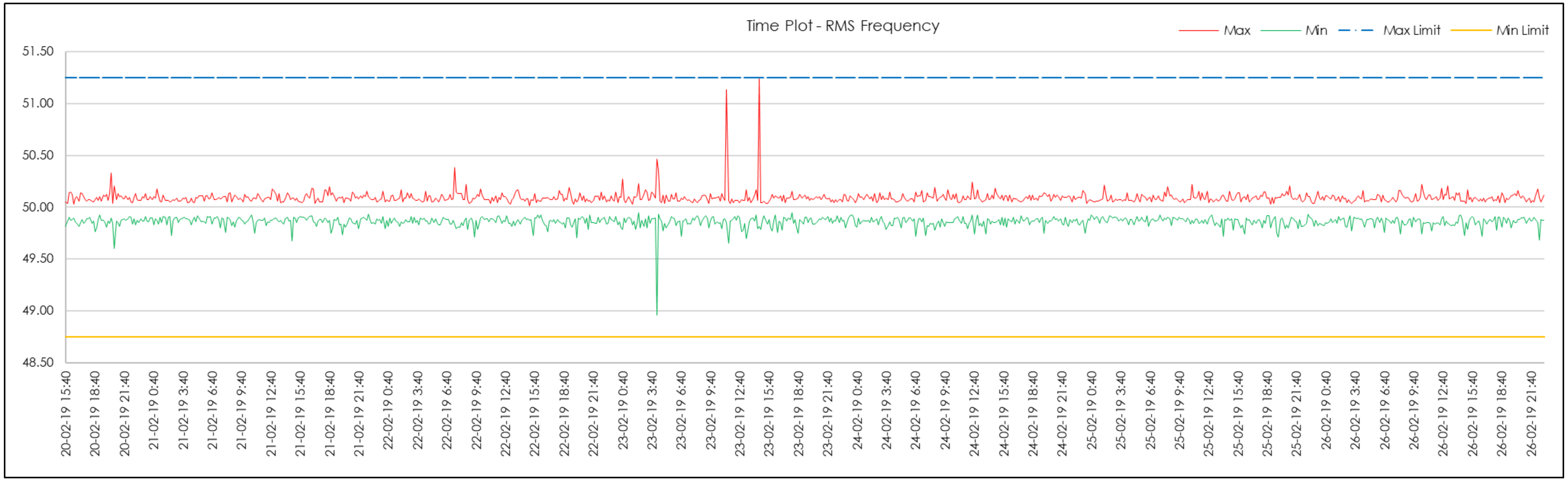

Figure 147 | STS1 Start Frequency measurements

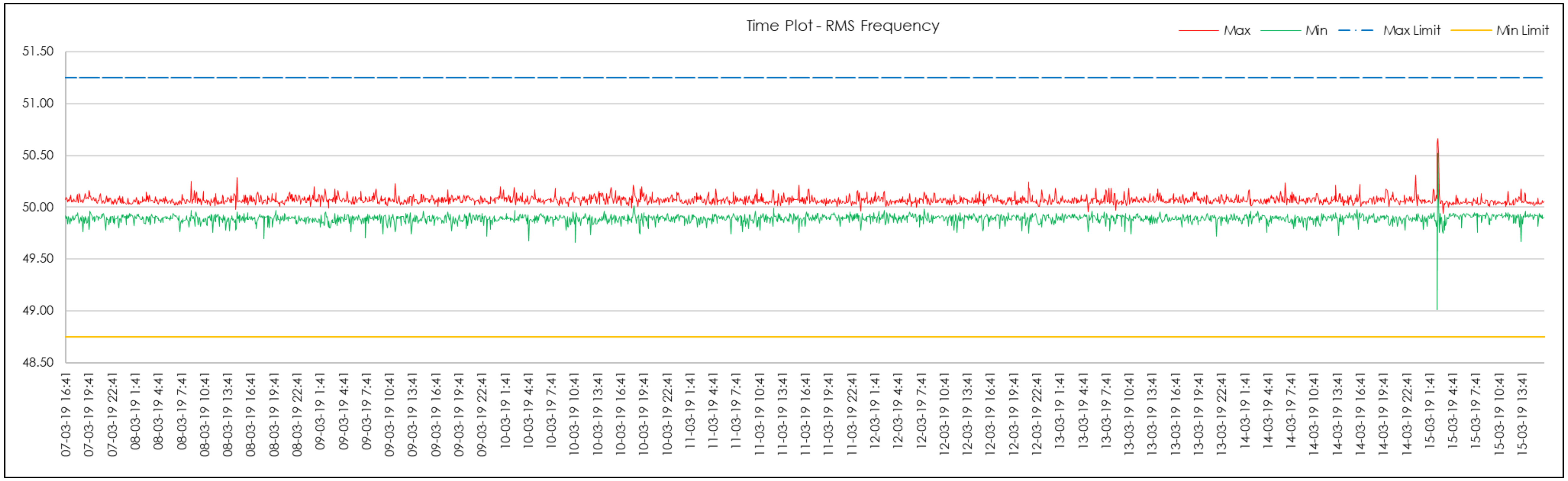

Figure 148 | STS1 End Frequency measurements

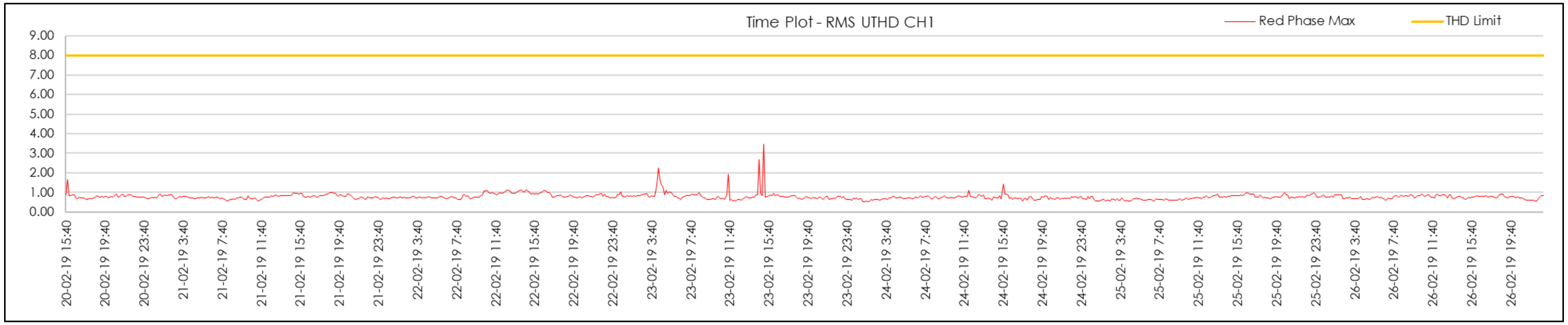

Figure 149 | STS1 Start U-THD measurements (Red Phase)

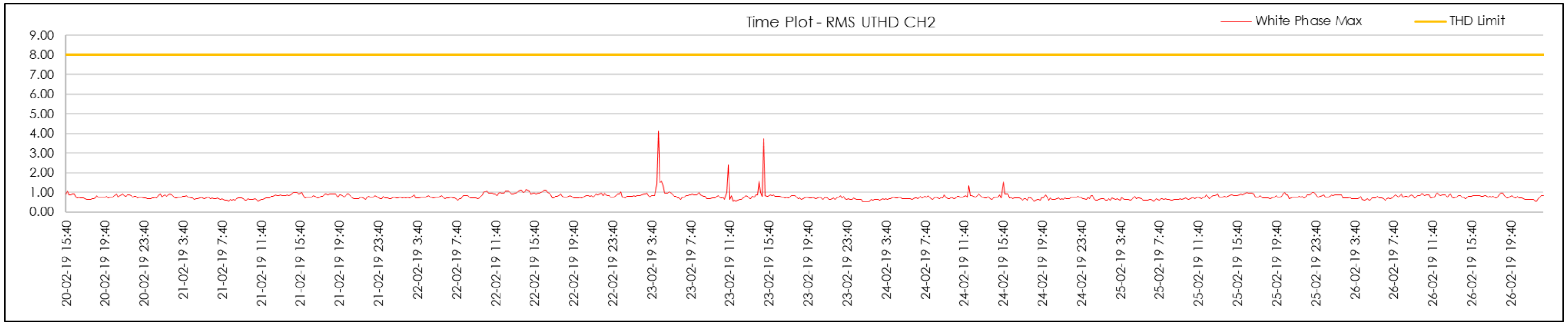

Figure 150 | STS1 Start U-THD measurements (White Phase)

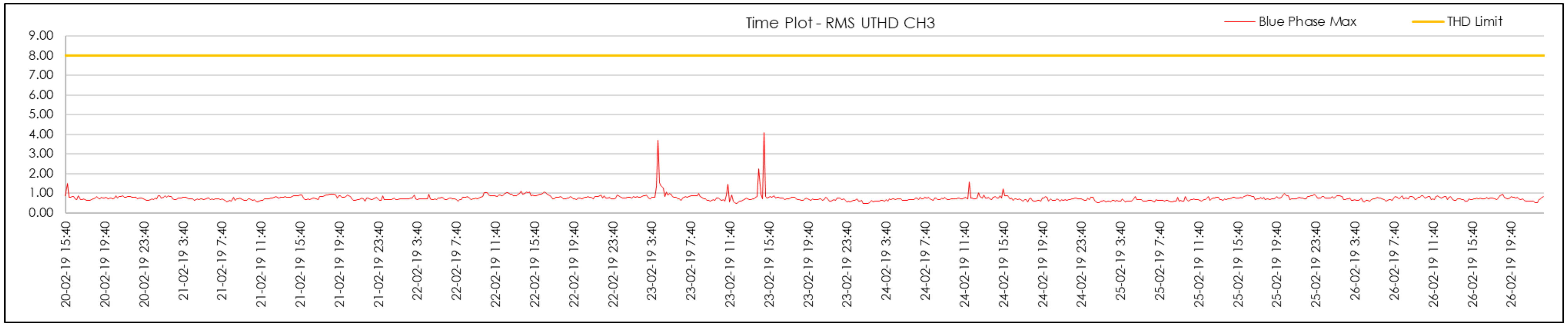

Figure 151 | STS1 Start U-THD measurements (Blue Phase)

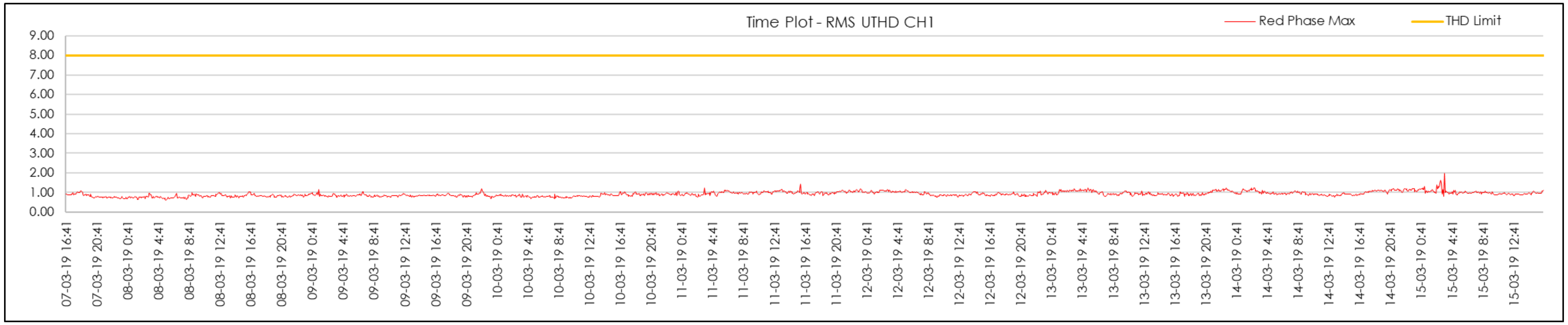

Figure 152 | STS1 End U-THD measurements (Red Phase)

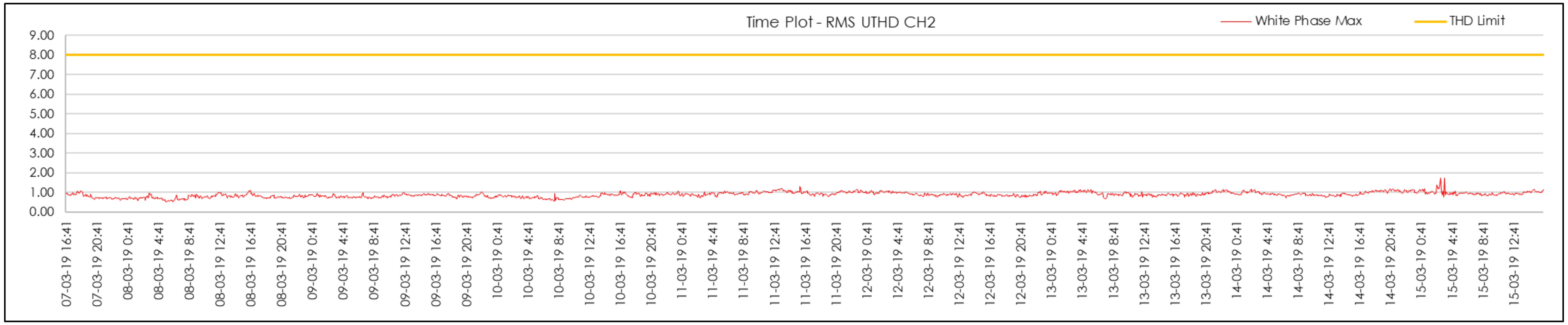

Figure 153 | STS1 End U-THD measurements (White Phase)

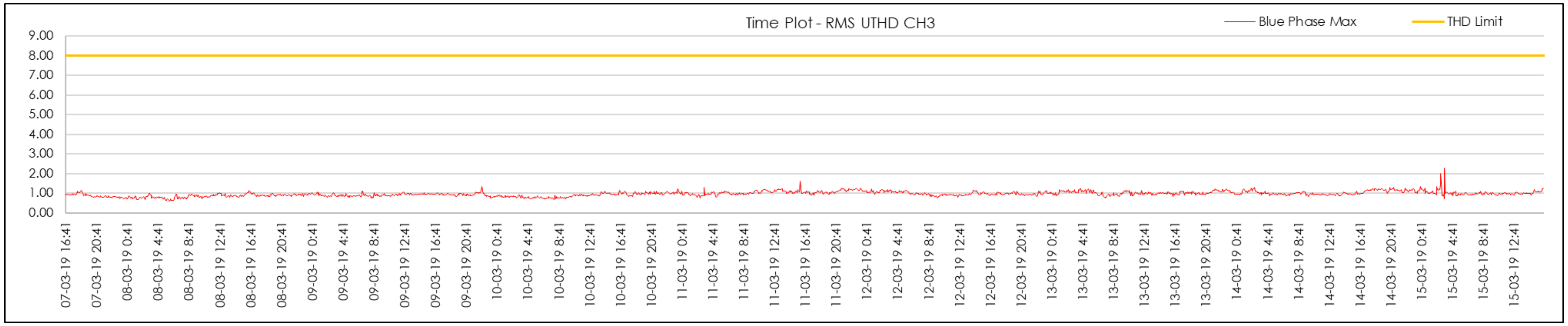

Figure 154 | STS1 End U-THD measurements (Blue Phase)

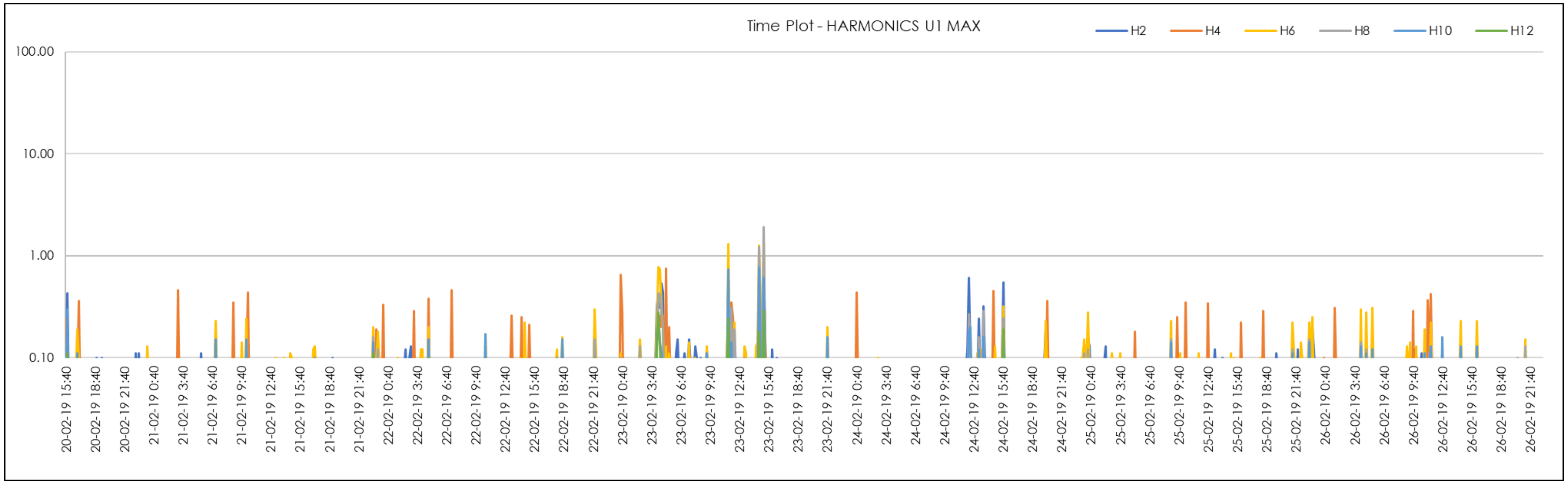

Figure 155 | STS1 Start Even 2nd-12th Harmonics (Red Phase)

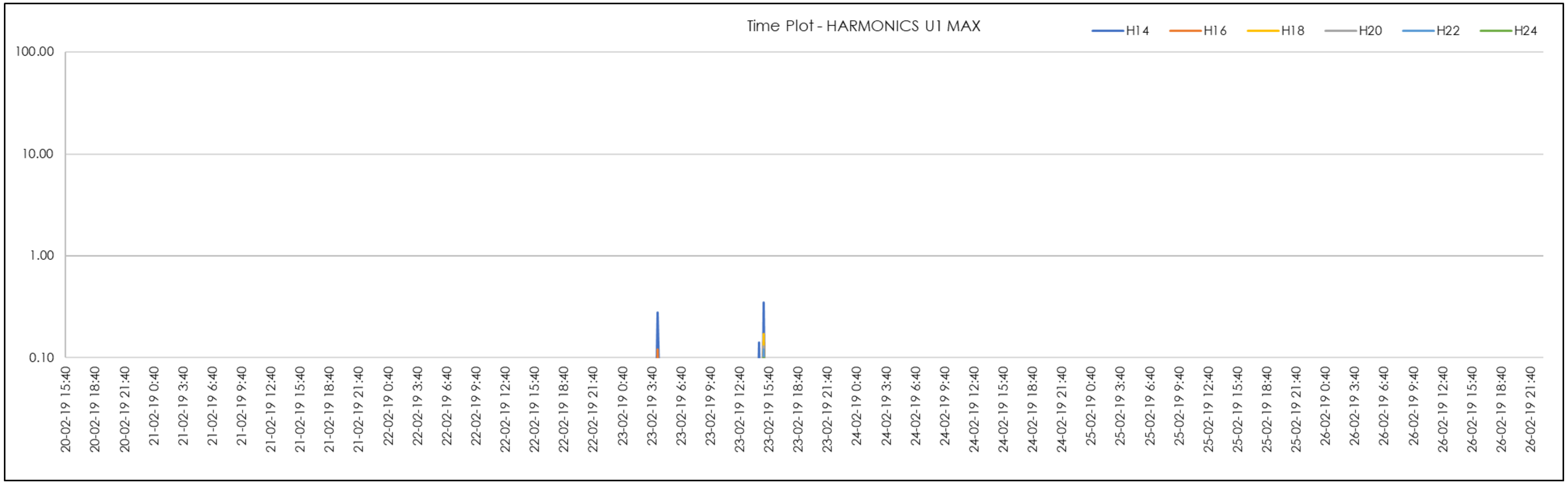

Figure 156 | STS1 Start Even 14th-24th Harmonics (Red Phase)

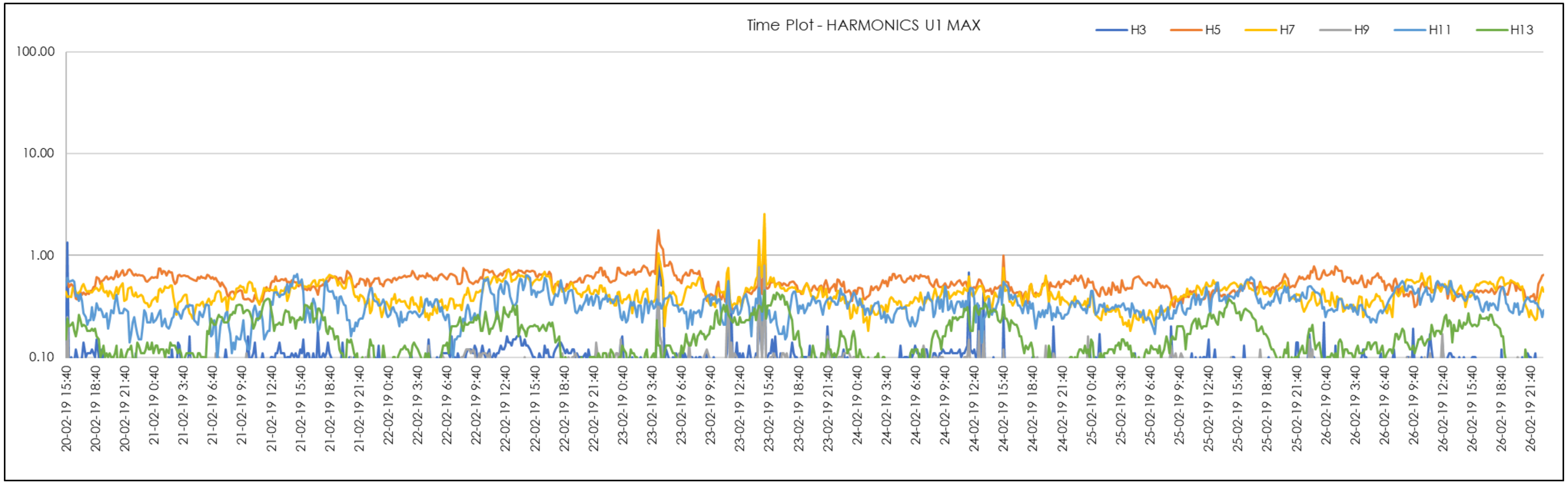

Figure 157 | STS1 Start Odd 3rd-13th Harmonics (Red Phase)

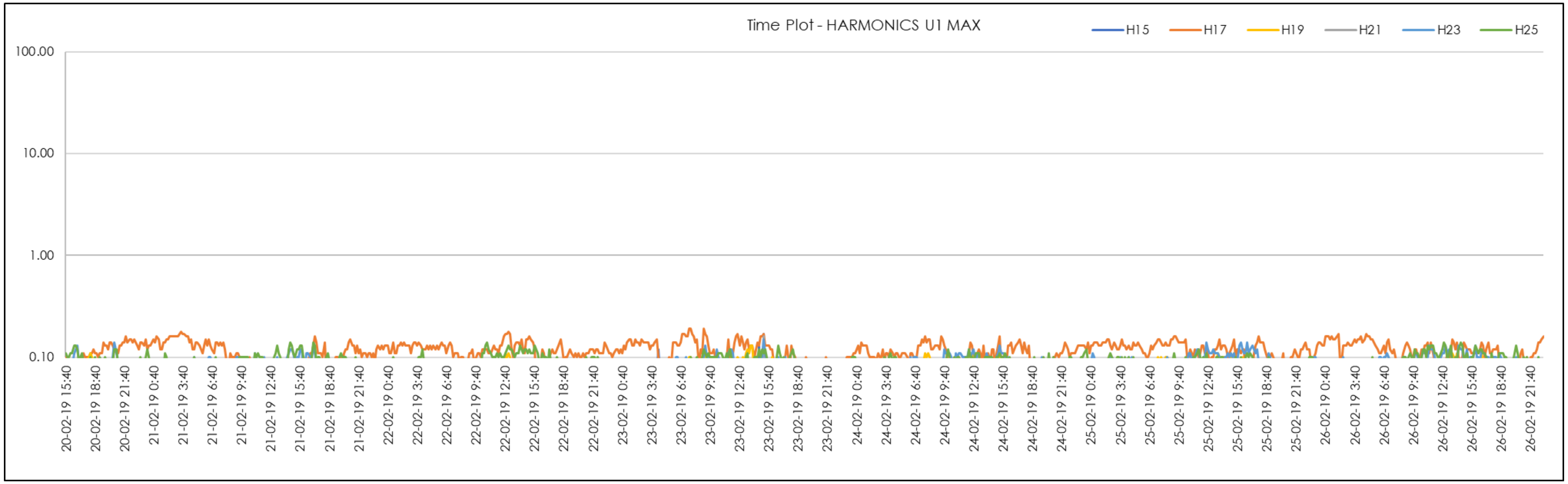

Figure 158 | STS1 Start Odd 15th-25th Harmonics (Red Phase)

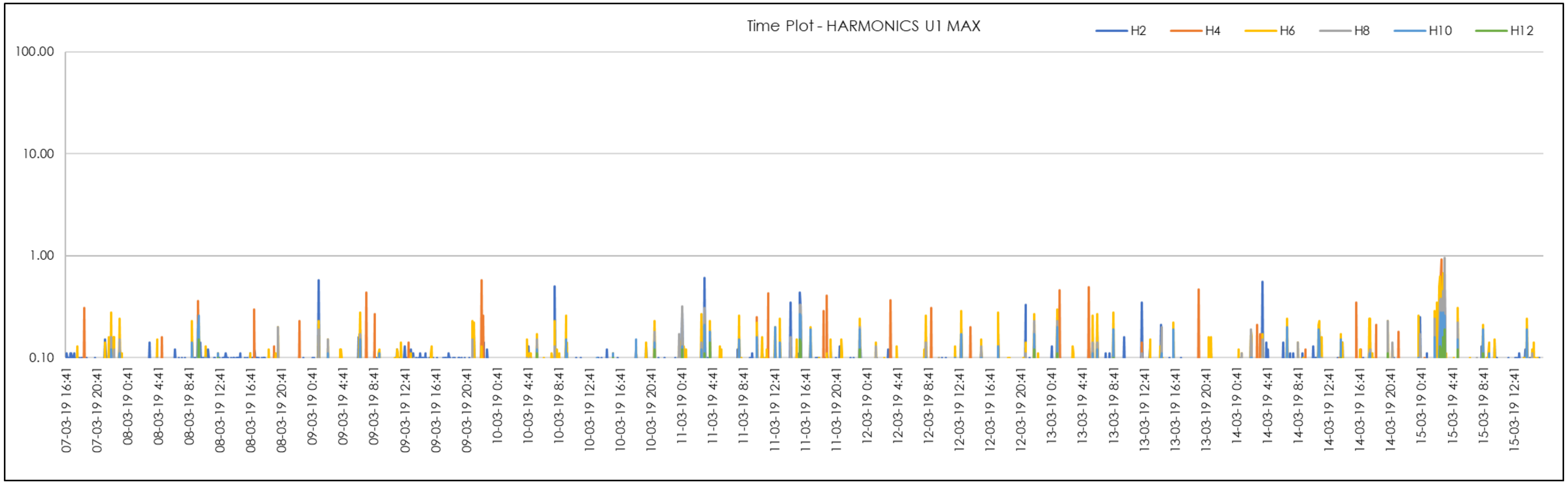

Figure 159 | STS1 End Even 2nd-12th Harmonics (Red Phase)

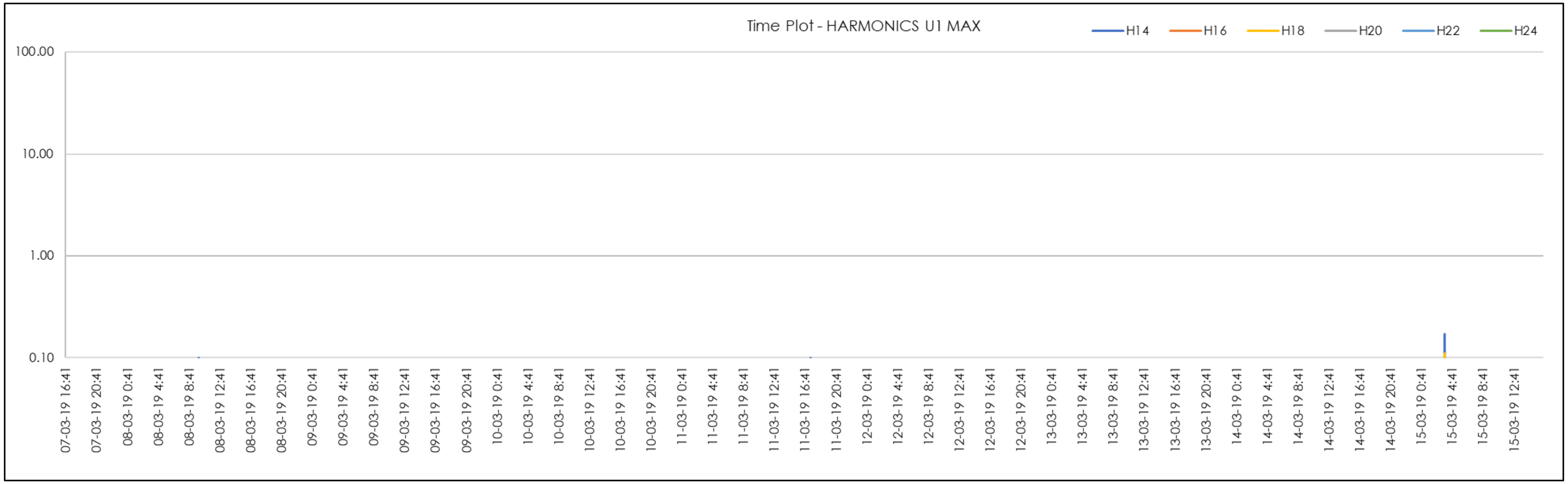

Figure 160 | STS1 End Even 14th-24th Harmonics (Red Phase)

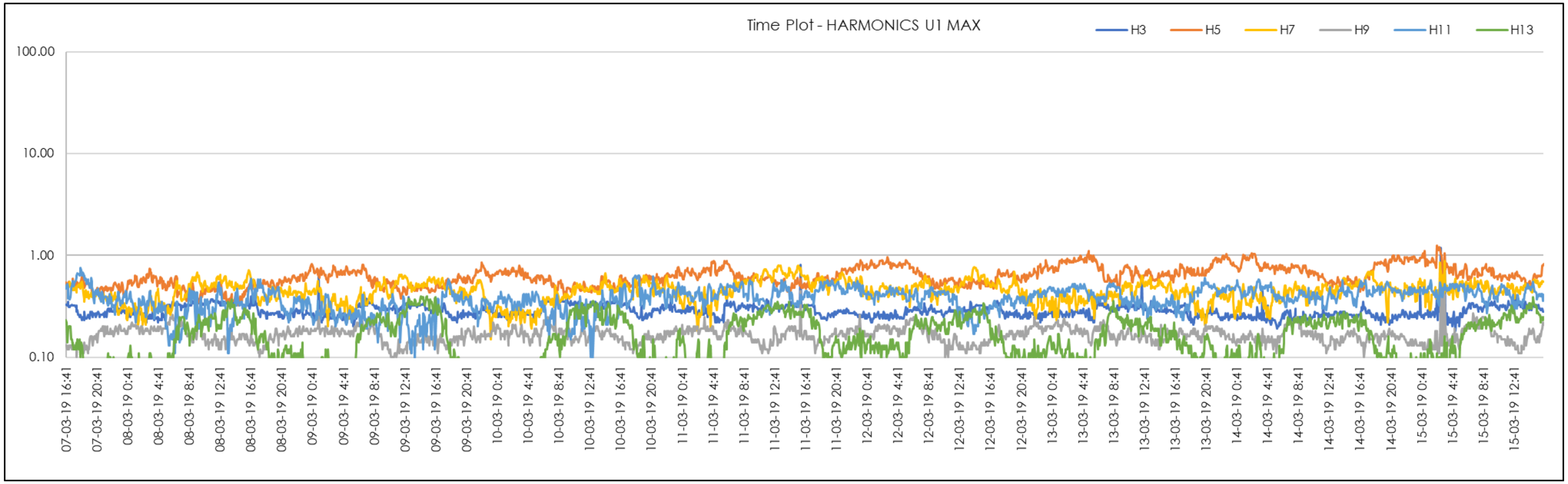

Figure 161 | STS1 End Odd 3rd-13th Harmonics (Red Phase)

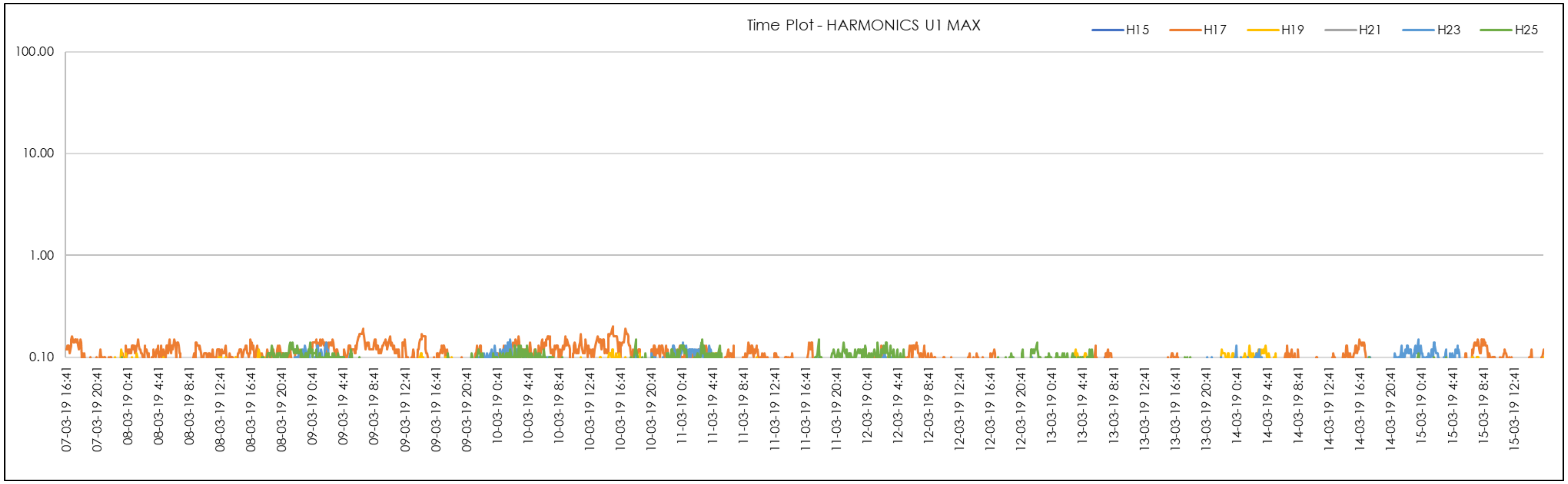

Figure 162 | STS1 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.6. FEEDER STS2 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

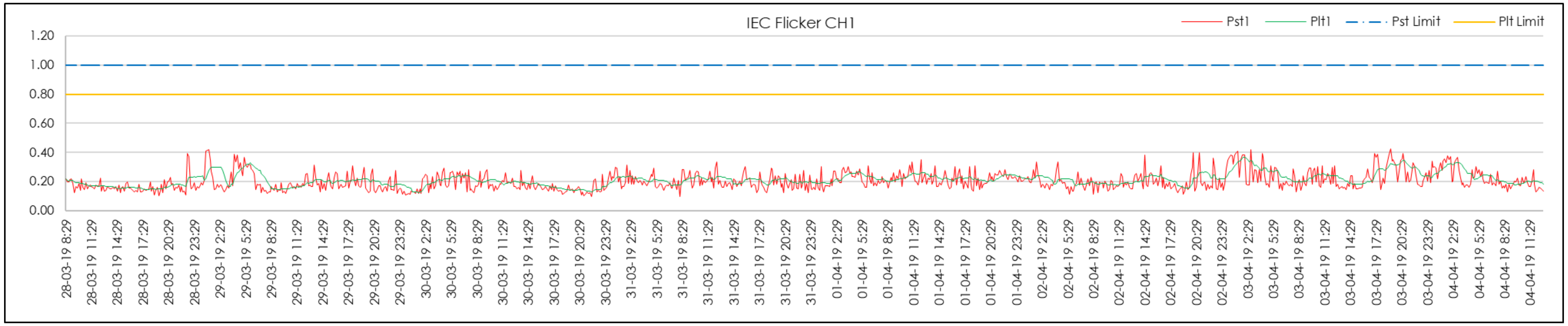

Figure 163 | STS2 Start Flicker measurements (Red Phase)

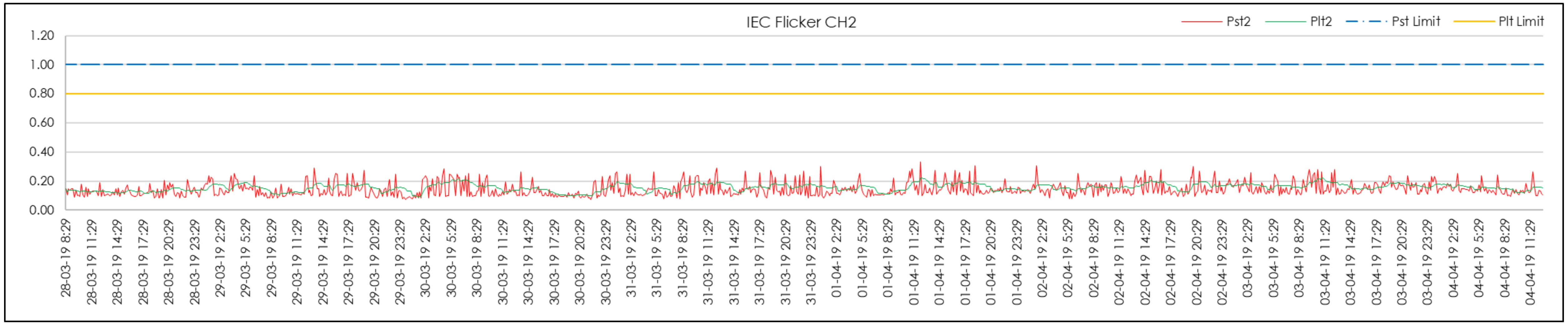

Figure 164 | STS2 Start Flicker measurements (White Phase)

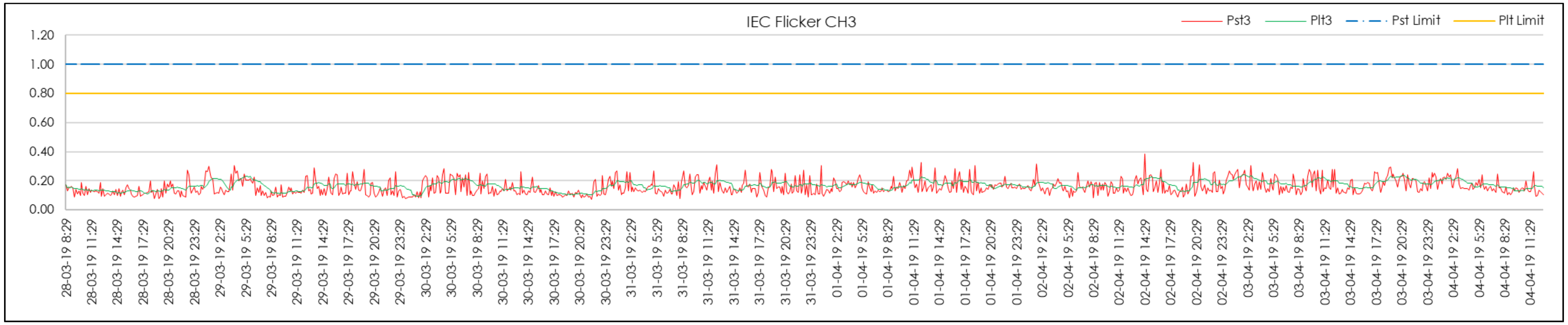

Figure 165 | STS2 Start Flicker measurements (Blue Phase)

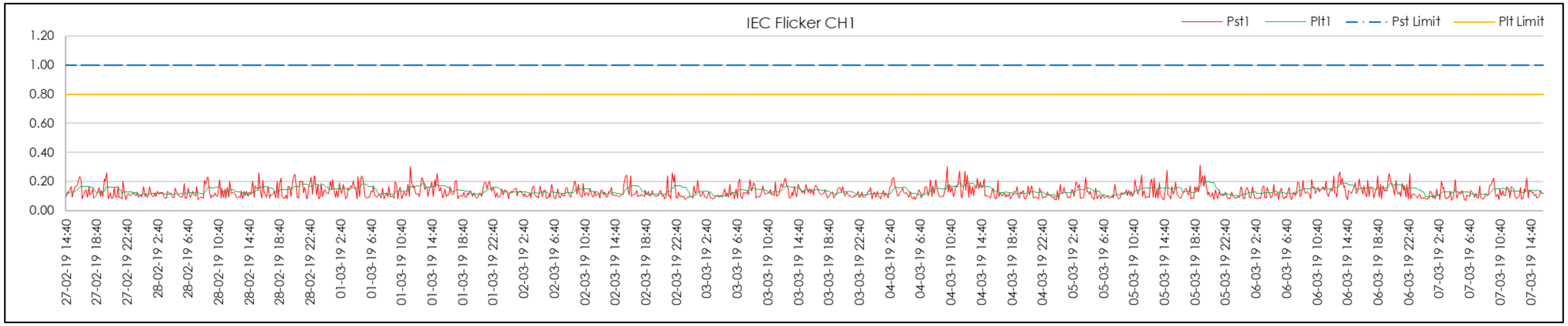

Figure 166 | STS2 End Flicker measurements (Red Phase)

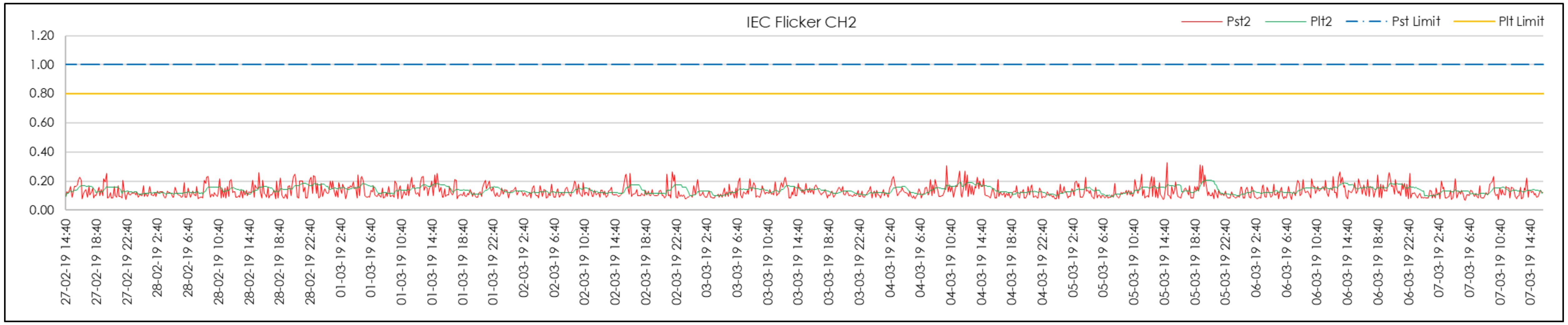

Figure 167 | STS2 End Flicker measurements (White Phase)

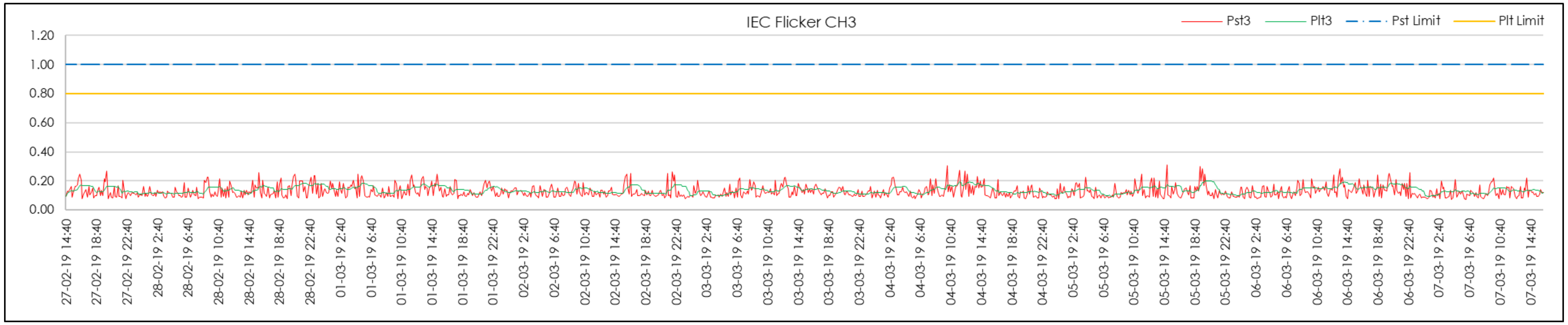

Figure 168 | STS2 End Flicker measurements (Blue Phase)

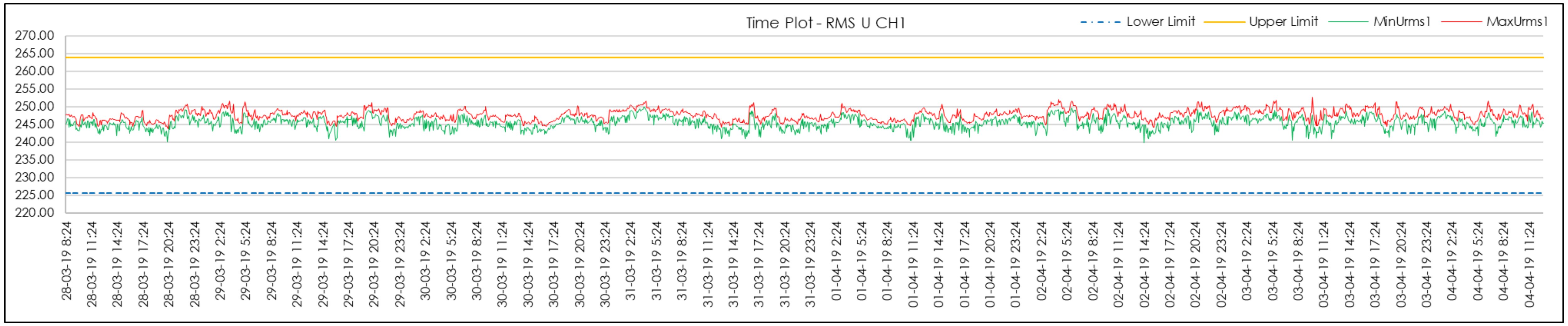

Figure 169 | STS2 Start Voltage measurements (Red Phase)

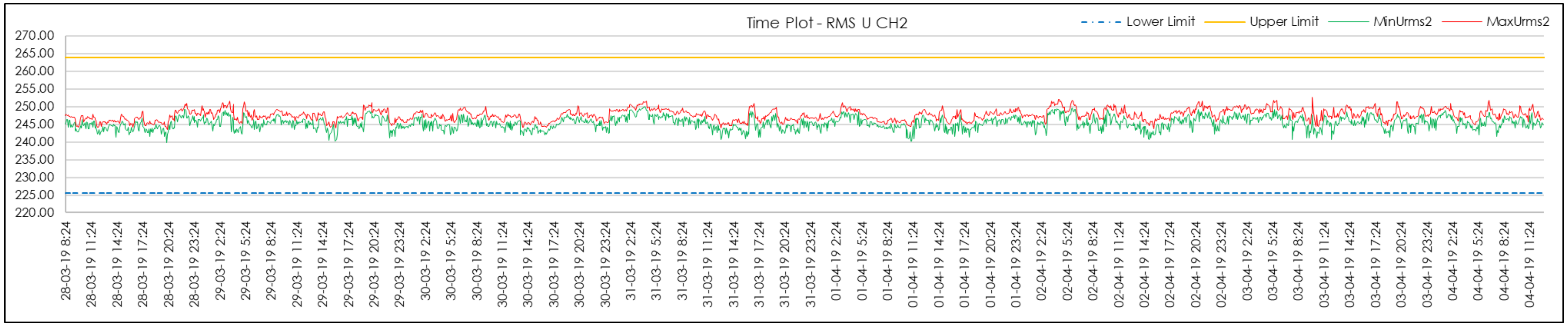

Figure 170 | STS2 Start Voltage measurements (White Phase)

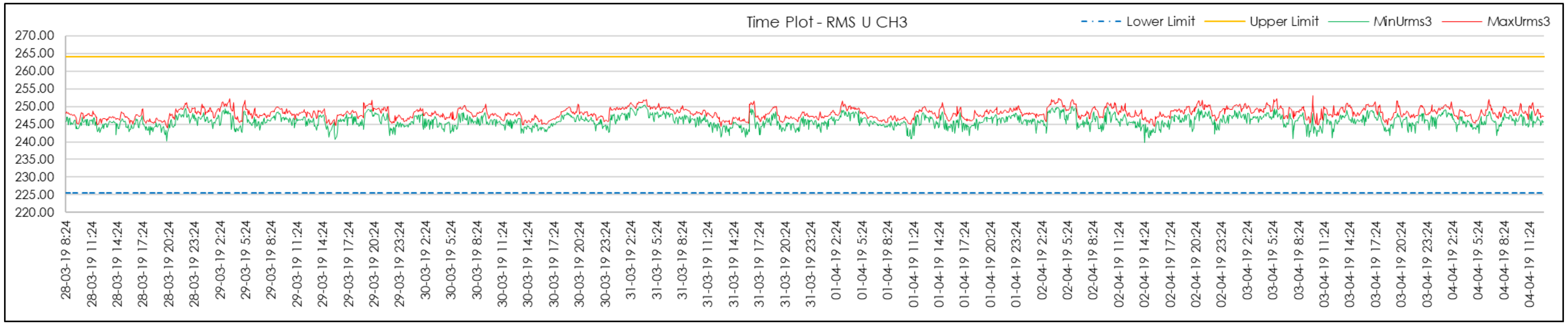

Figure 171 | STS2 Start Voltage measurements (Blue Phase)

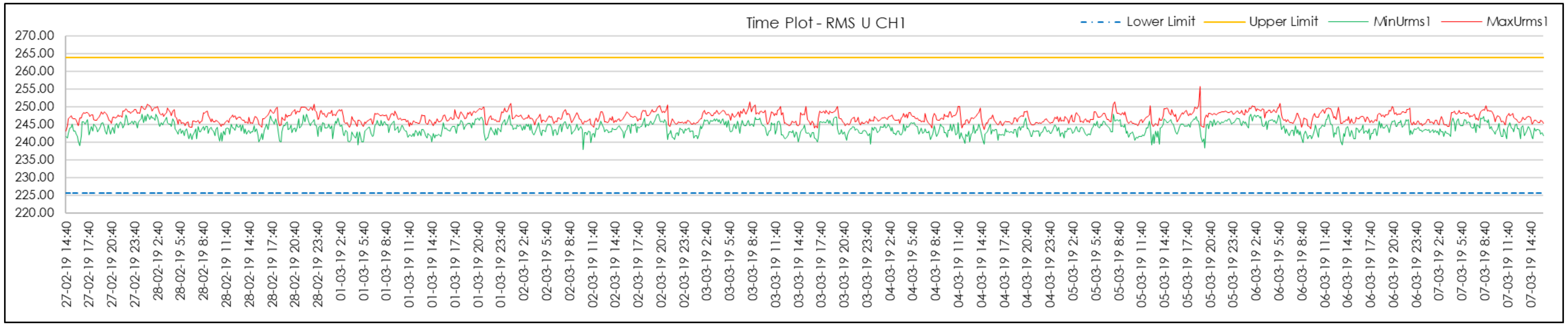

Figure 172 | STS2 End Voltage measurements (Red Phase)

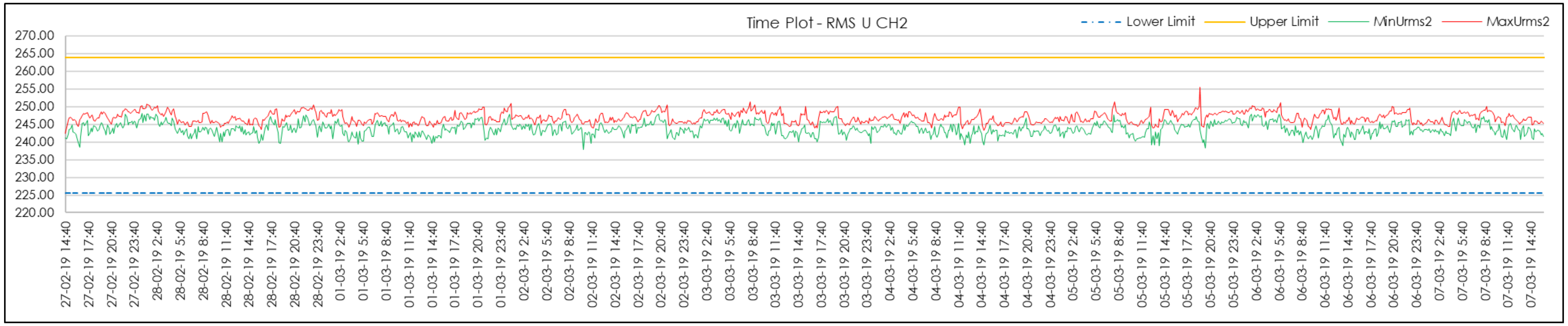

Figure 173 | STS2 End Voltage measurements (White Phase)

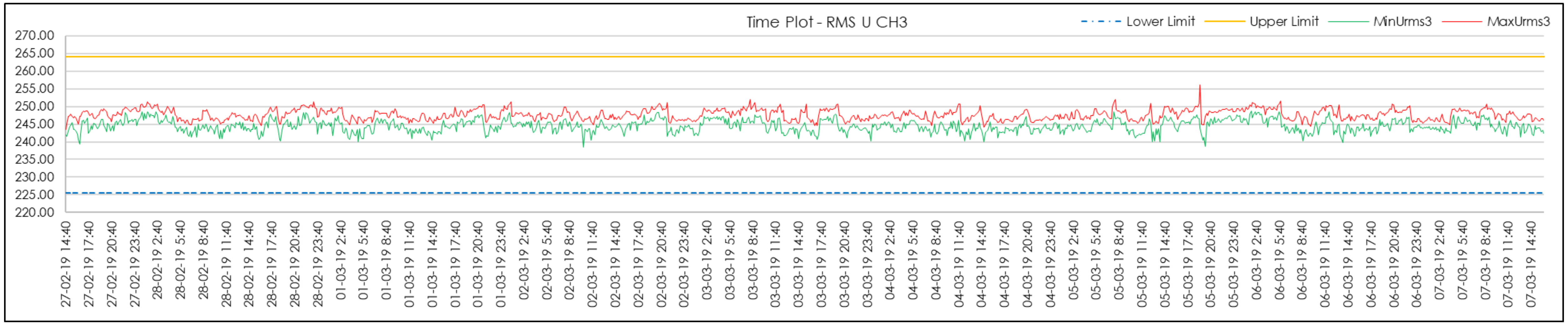

Figure 174 | STS2 End Voltage measurements (Blue Phase)

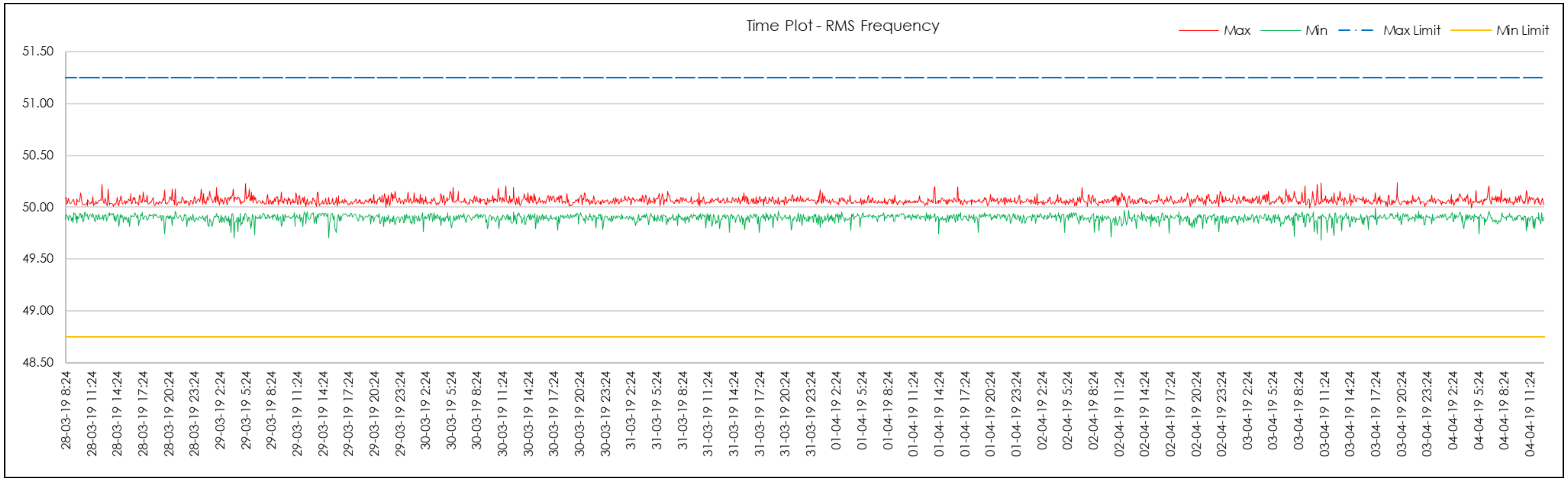

Figure 175 | STS2 Start Frequency measurements

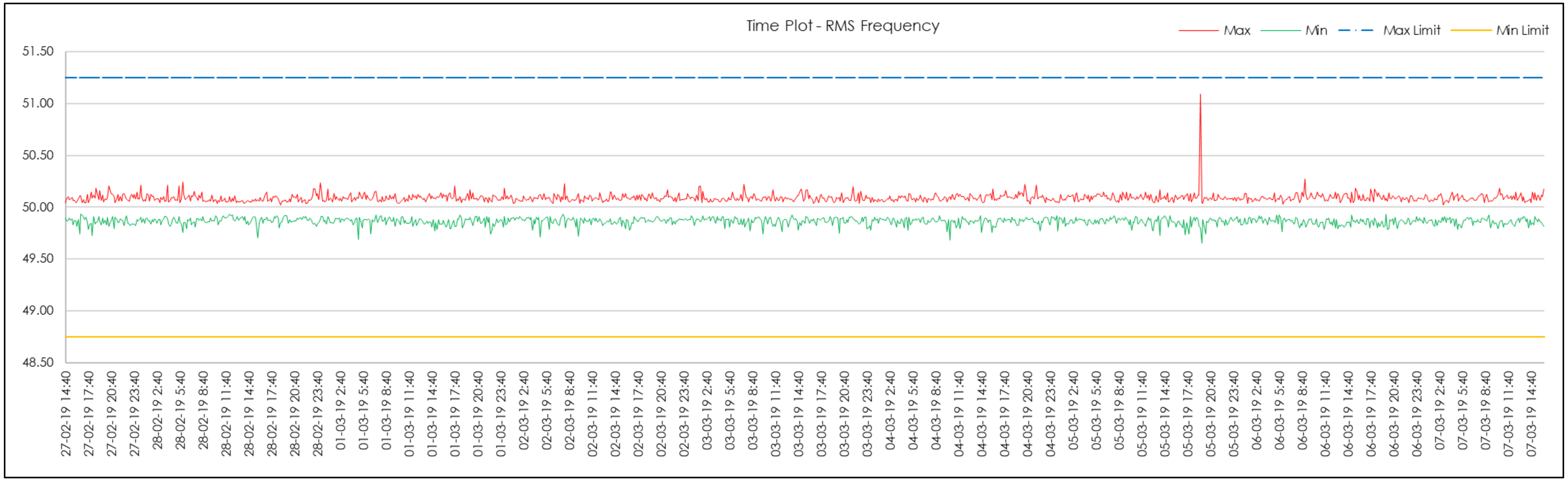

Figure 176 | STS2 End Frequency measurements

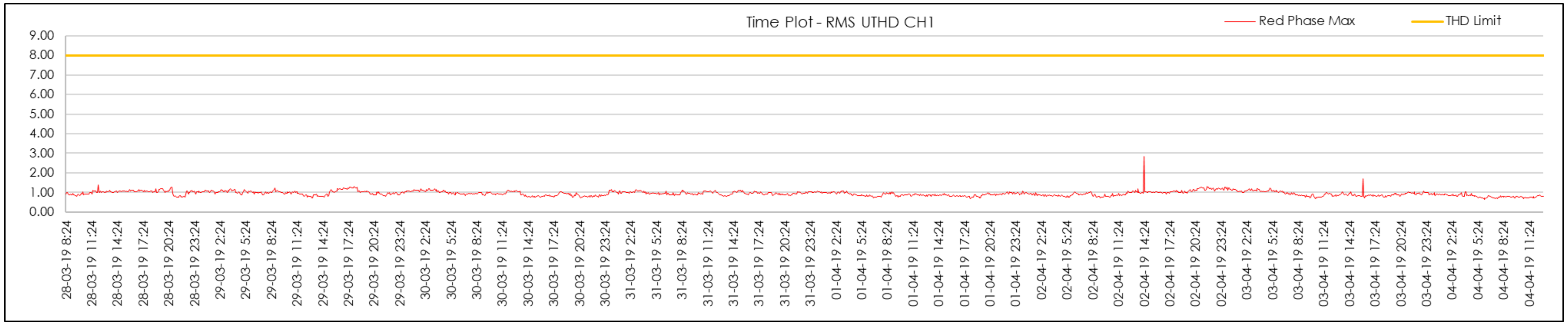

Figure 177 | STS2 Start U-THD measurements (Red Phase)

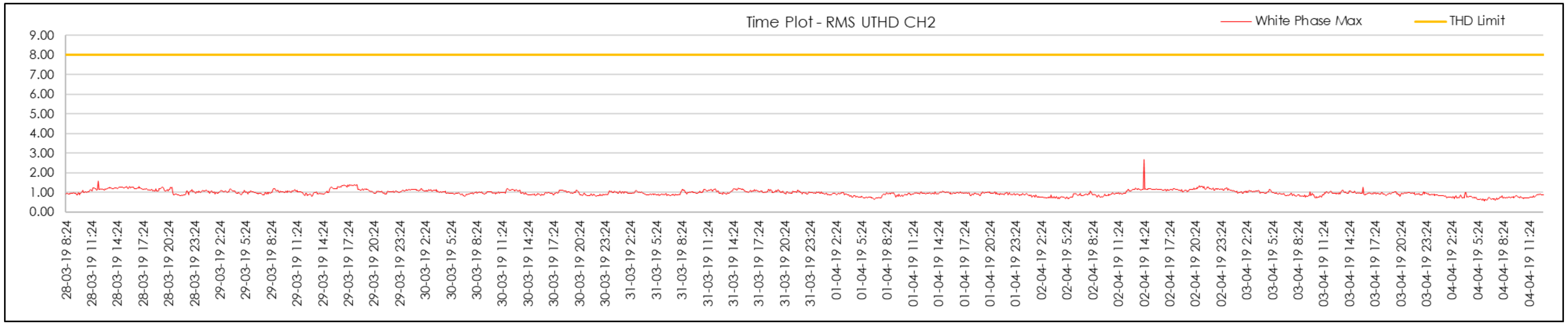

Figure 178 | STS2 Start U-THD measurements (White Phase)

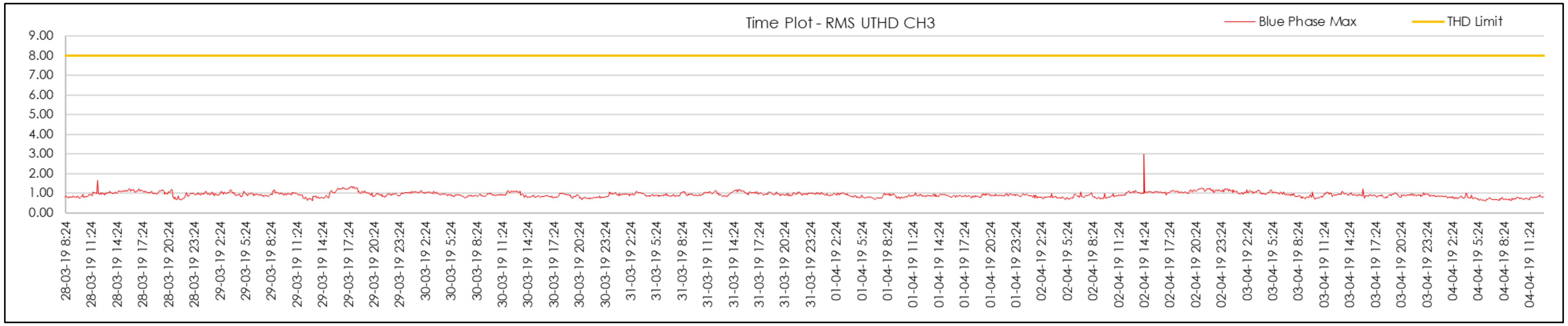

Figure 179 | STS2 Start U-THD measurements (Blue Phase)

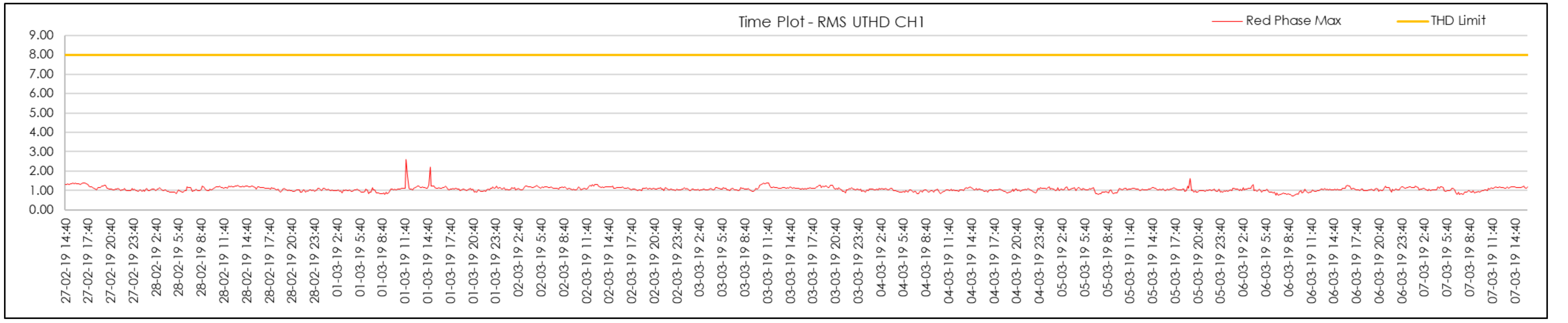

Figure 180 | STS2 End U-THD measurements (Red Phase)

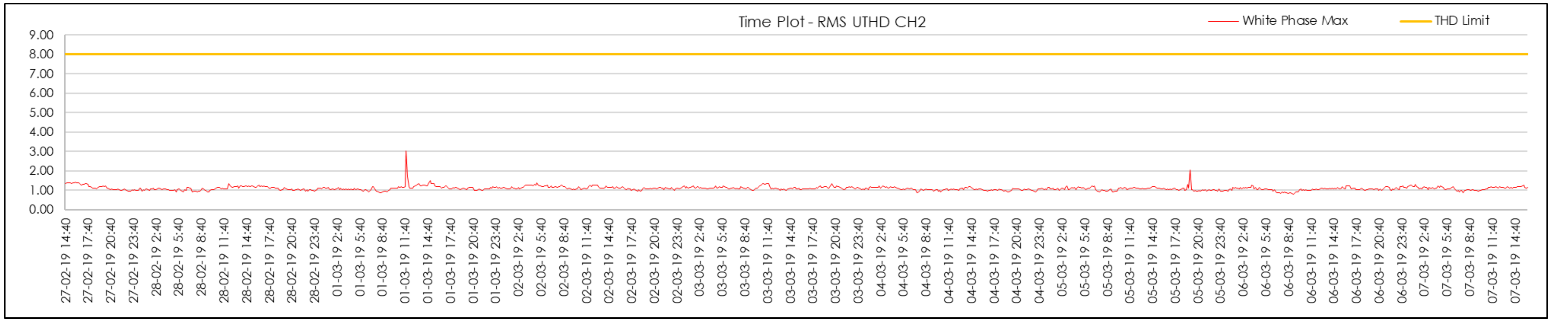

Figure 181 | STS2 End U-THD measurements (White Phase)

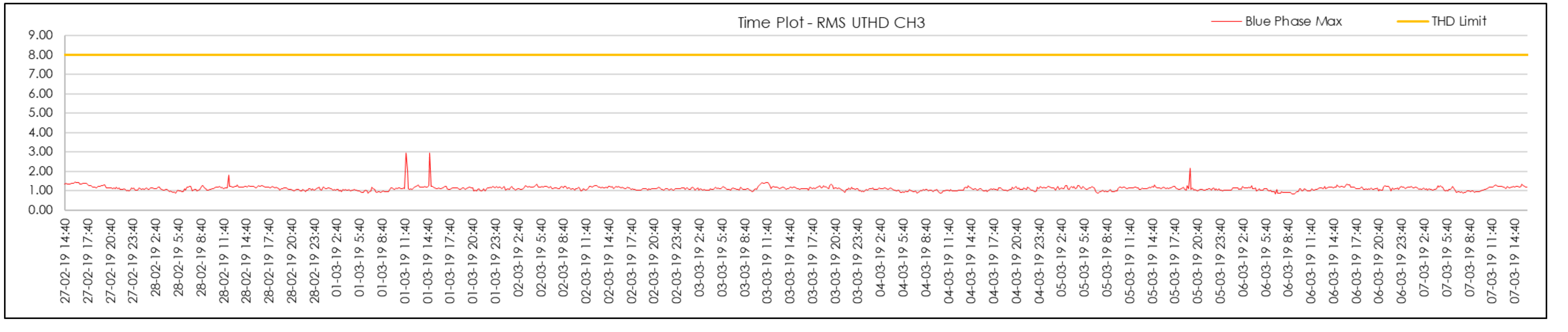

Figure 182 | STS2 End U-THD measurements (Blue Phase)

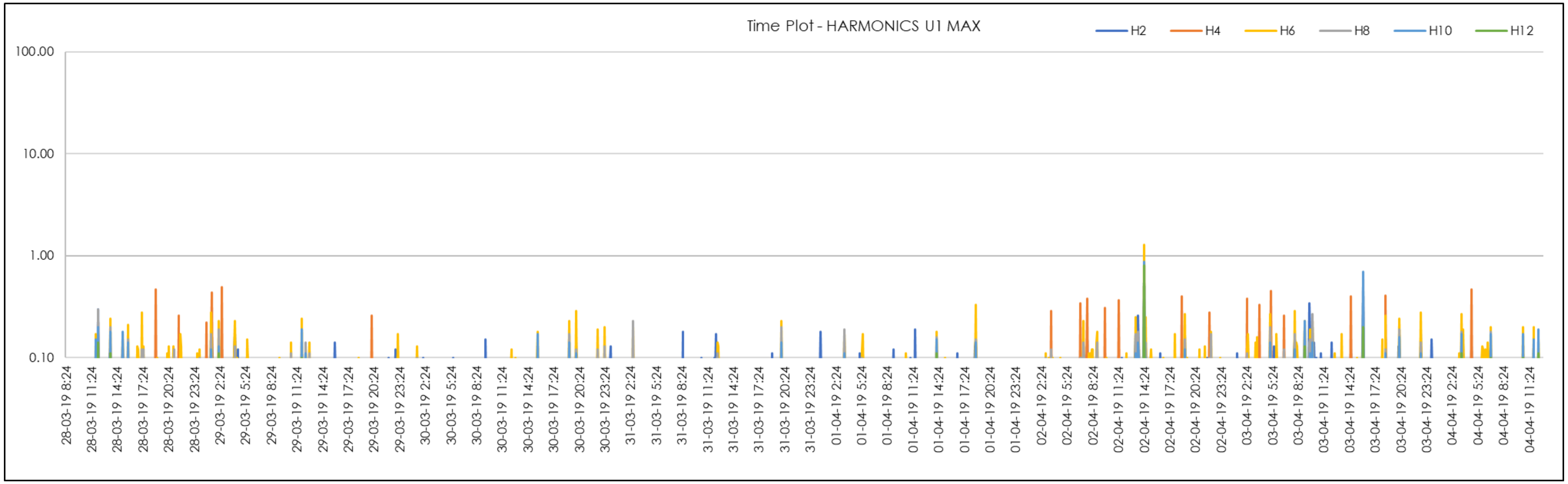

Figure 183 | STS2 Start Even 2nd-12th Harmonics (Red Phase)

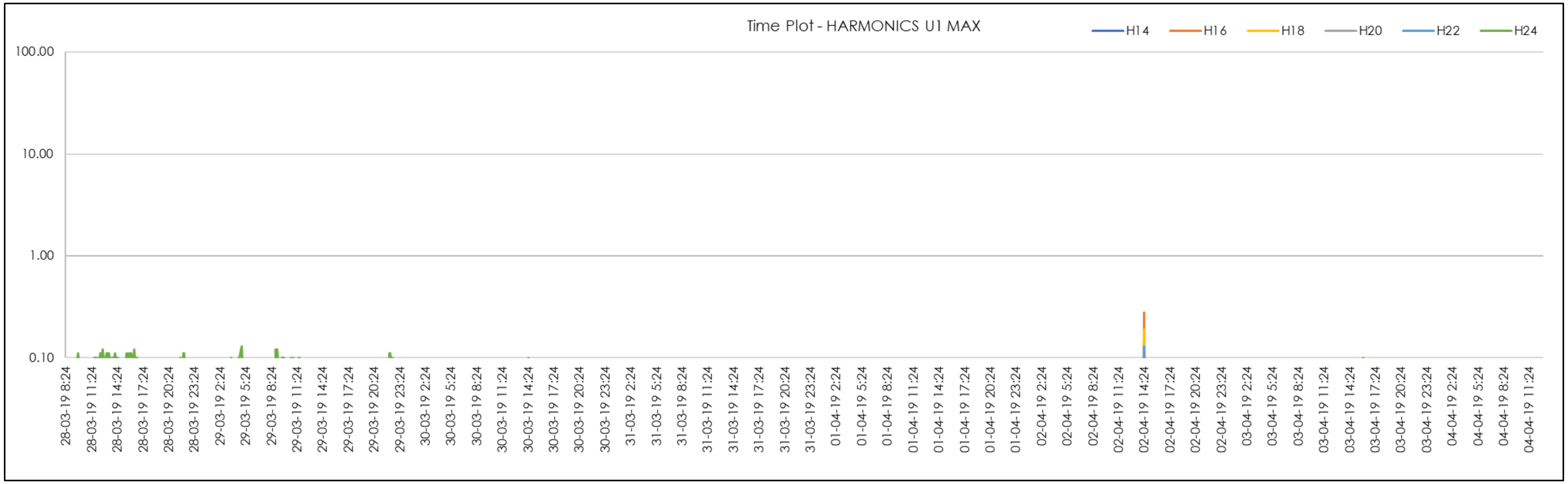

Figure 184 | STS2 Start Even 14th-24th Harmonics (Red Phase)

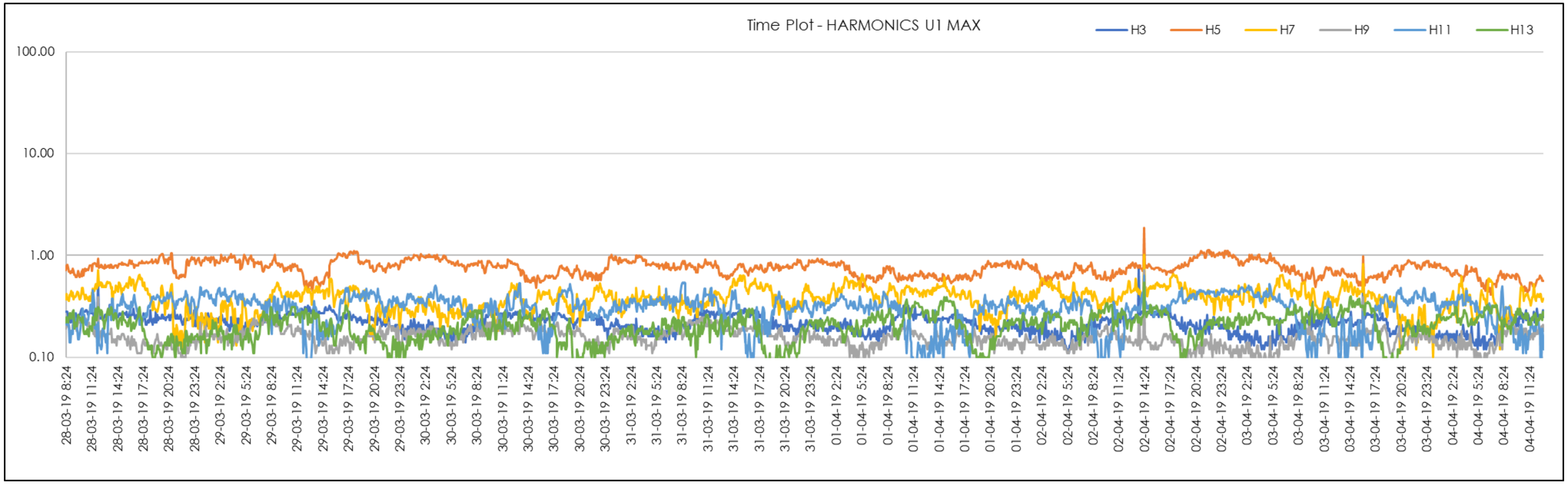

Figure 185 | STS2 Start Odd 3rd-13th Harmonics (Red Phase)

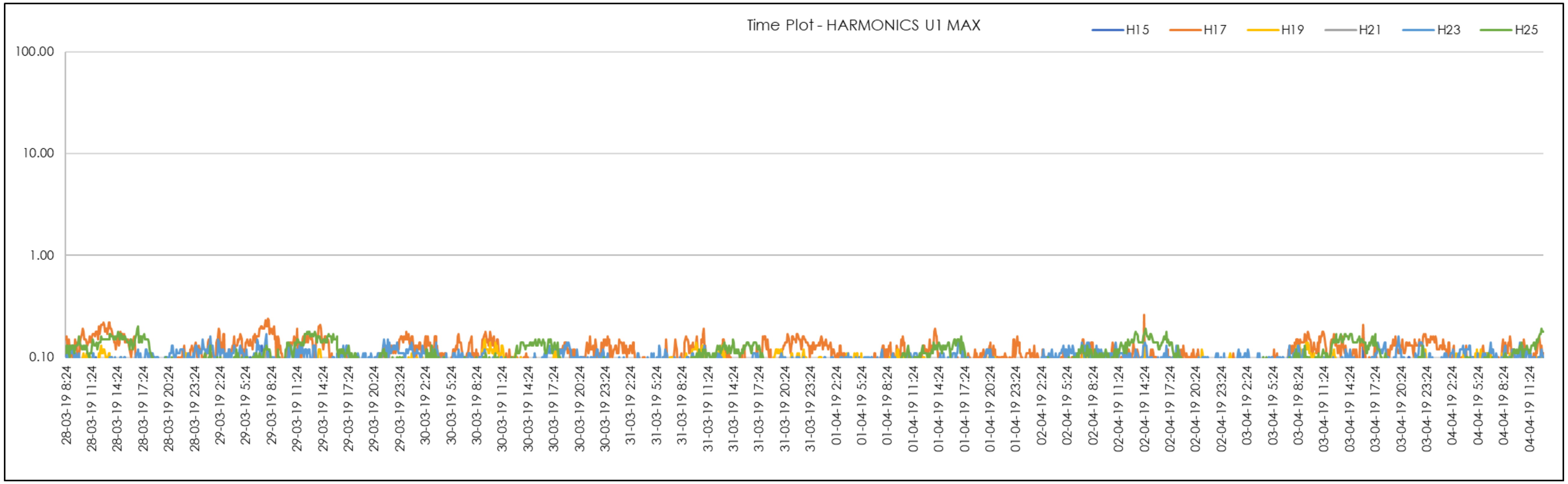

Figure 186 | STS2 Start Odd 15th-25th Harmonics (Red Phase)

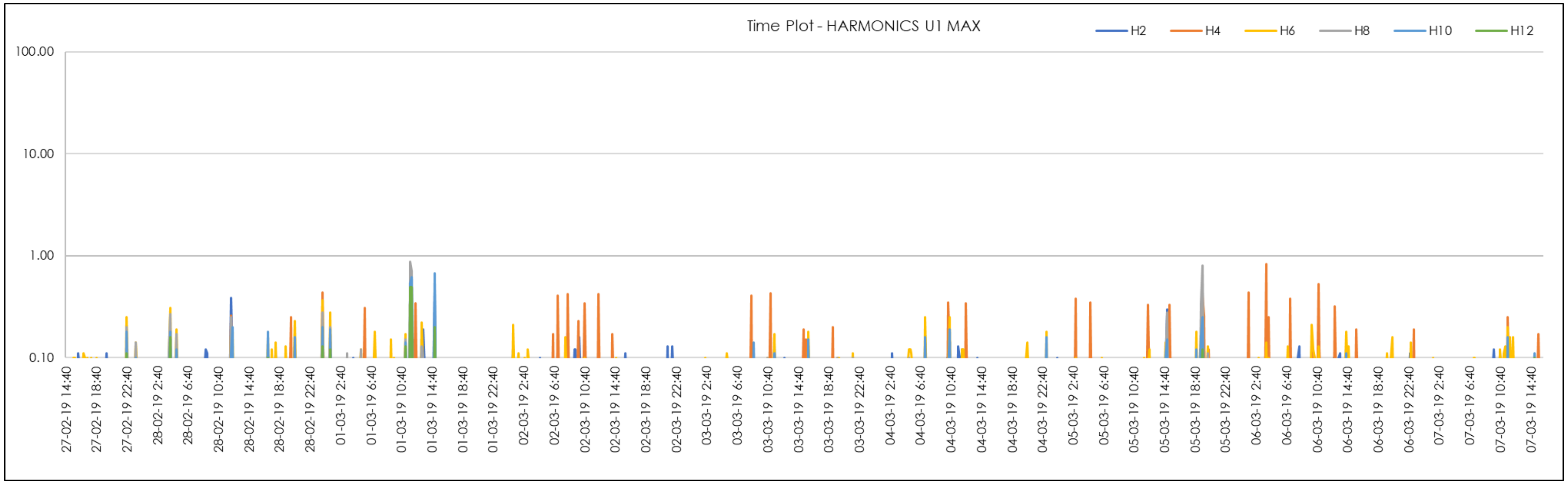

Figure 187 | STS2 End Even 2nd-12th Harmonics (Red Phase)

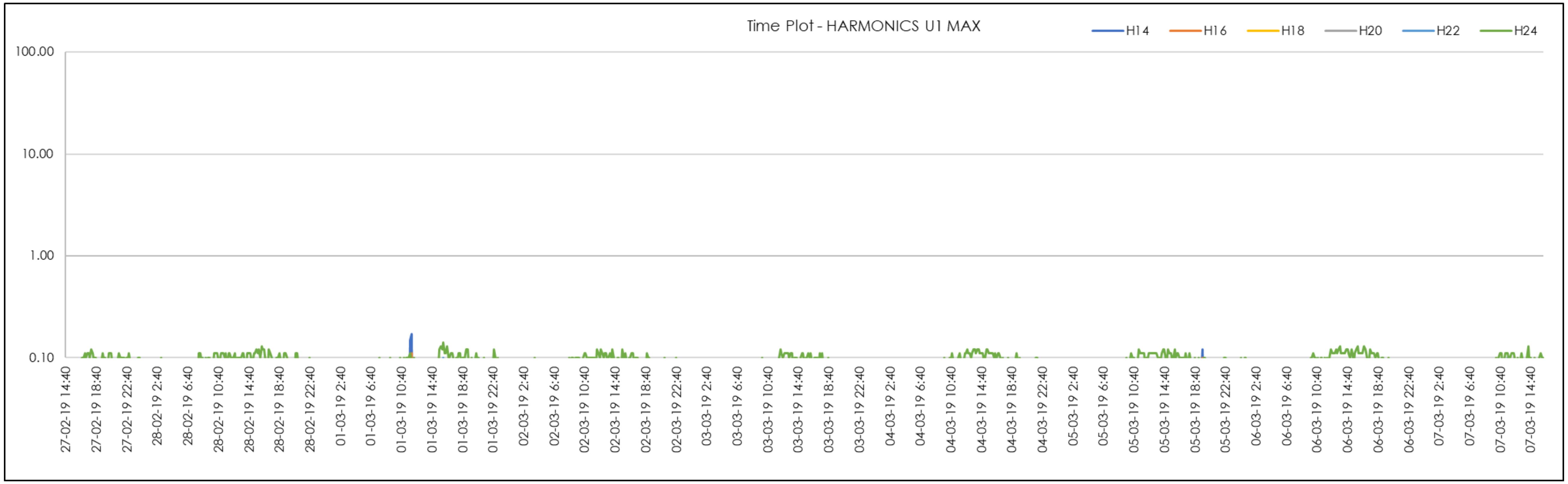

Figure 188 | STS2 End Even 14th-24th Harmonics (Red Phase)

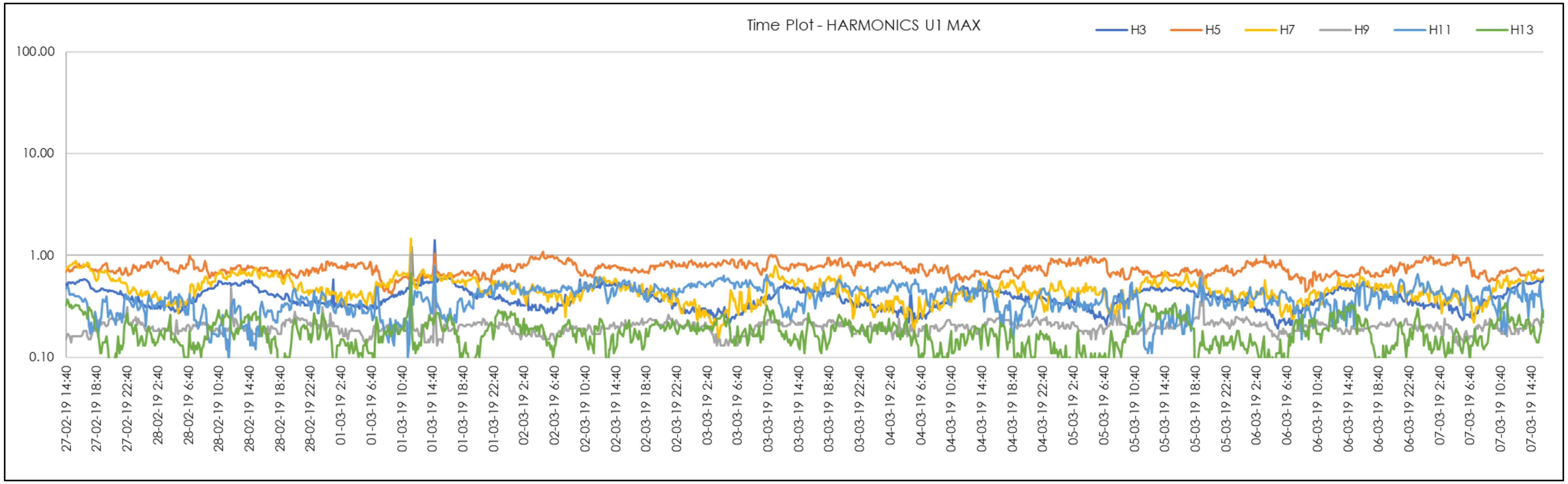

Figure 189 | STS2 End Odd 3rd-13th Harmonics (Red Phase)

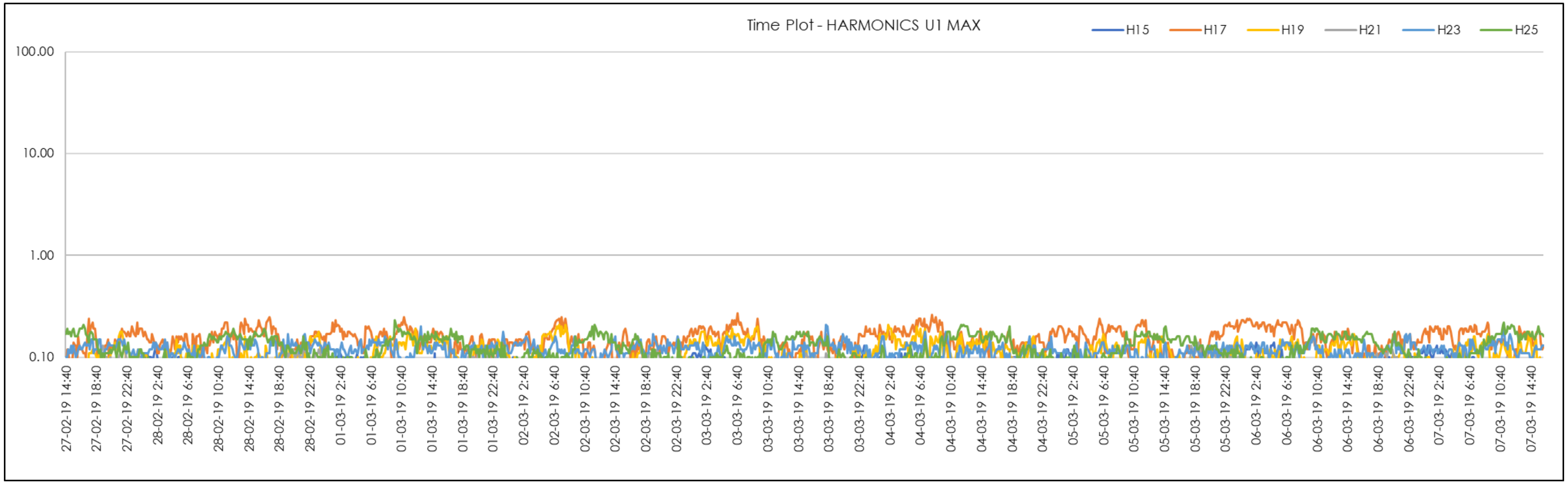

Figure 190 | STS2 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.7. FEEDER STS4 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

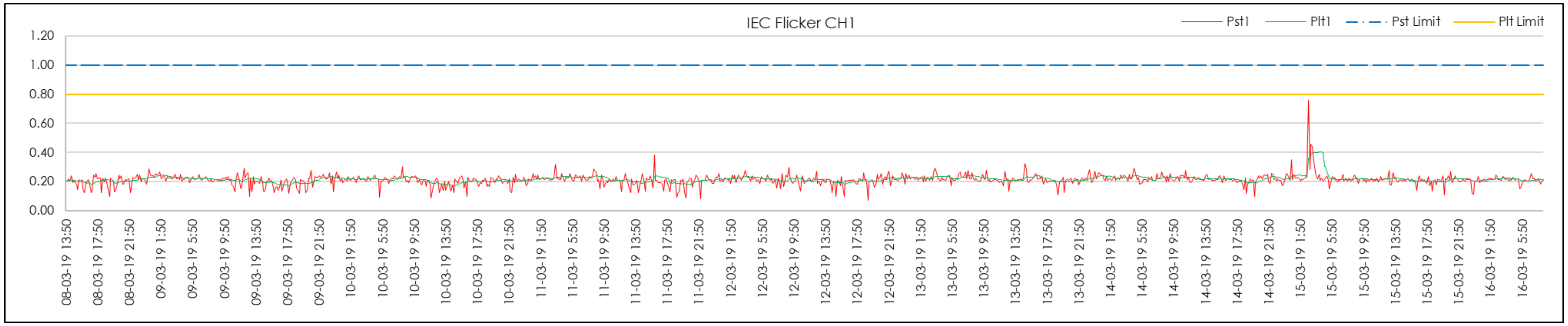

Figure 191 | STS4 Start Flicker measurements (Red Phase)

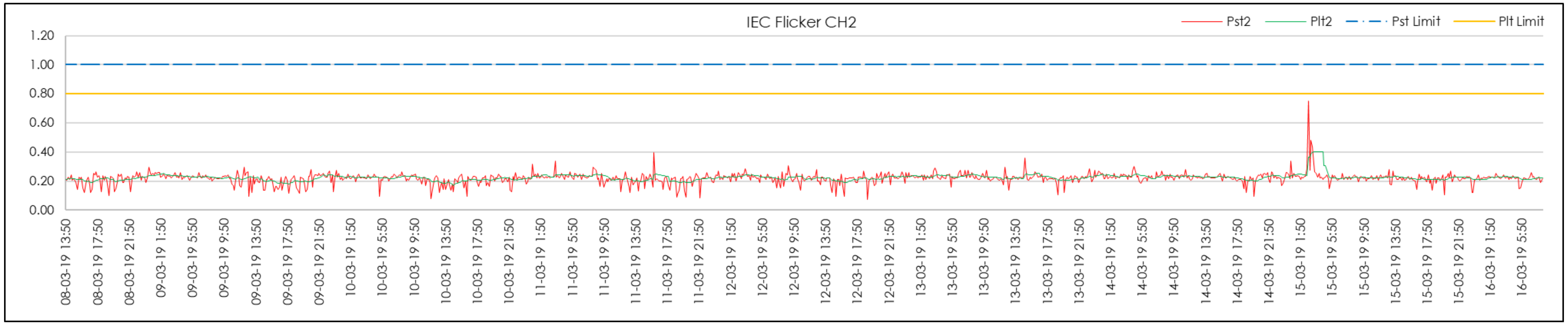

Figure 192 | STS4 Start Flicker measurements (White Phase)

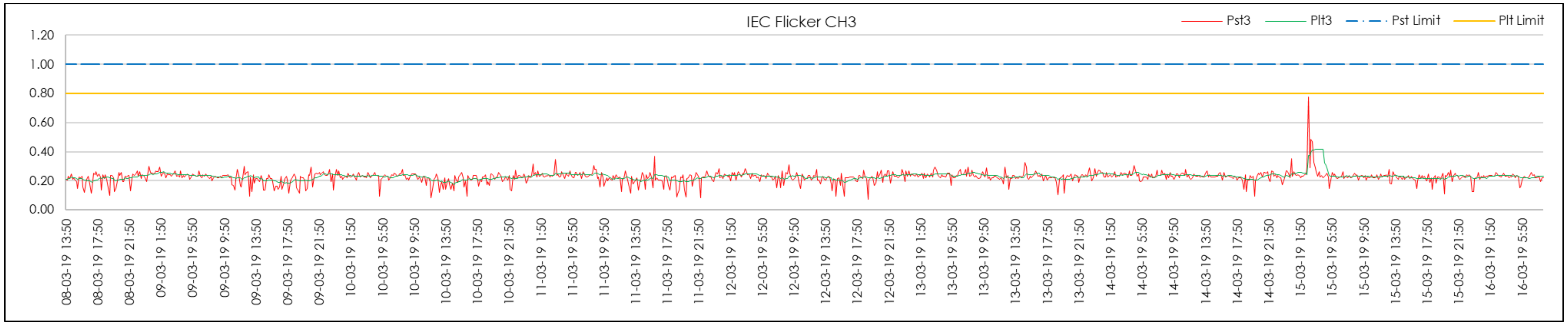

Figure 193 | STS4 Start Flicker measurements (Blue Phase)

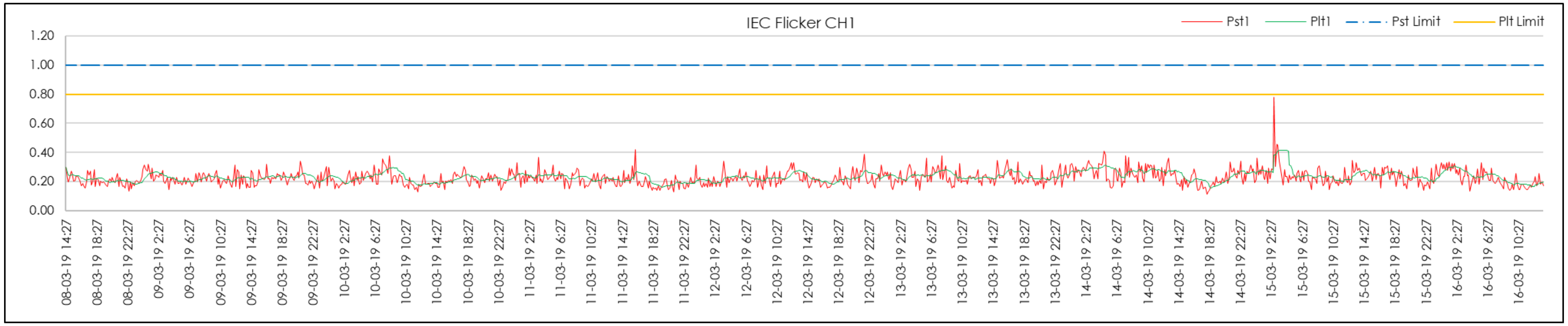

Figure 194 | STS4 End Flicker measurements (Red Phase)

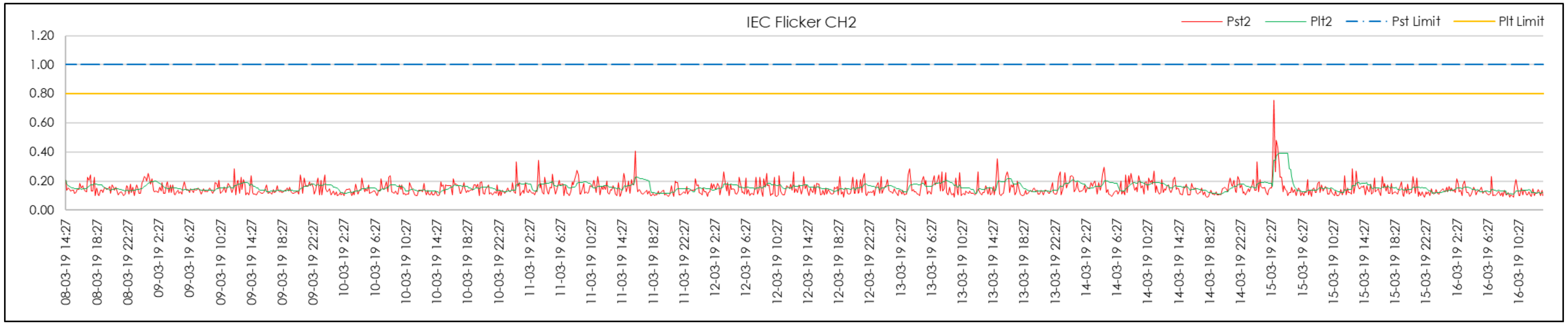

Figure 195 | STS4 End Flicker measurements (White Phase)

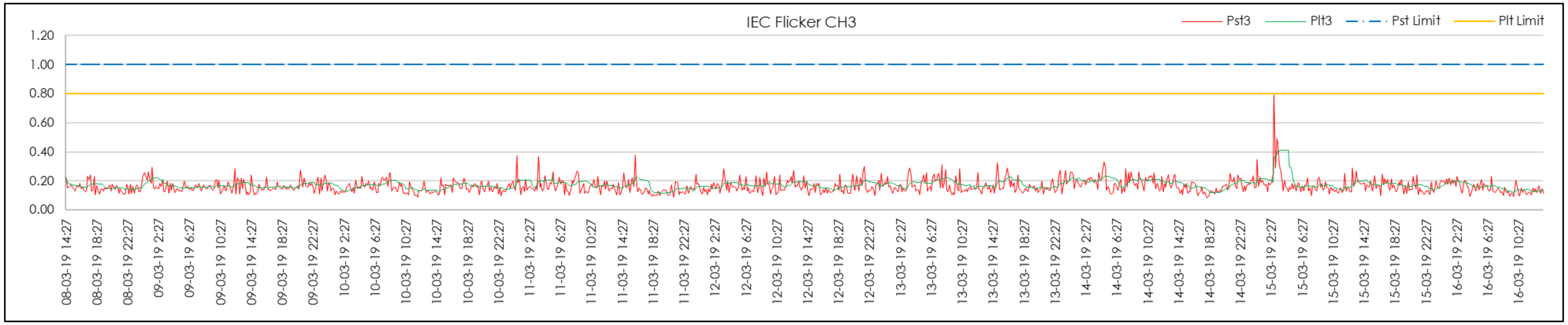

Figure 196 | STS4 End Flicker measurements (Blue Phase)

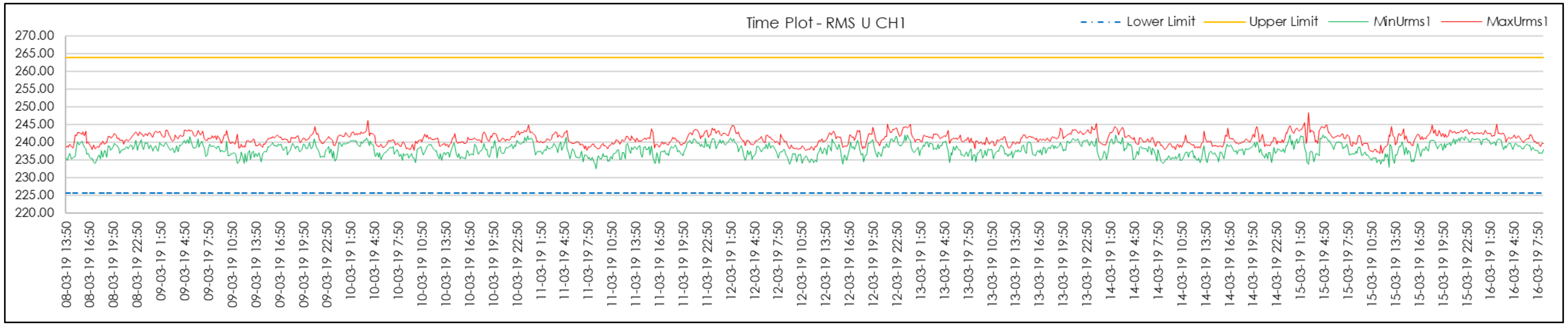

Figure 197 | STS4 Start Voltage measurements (Red Phase)

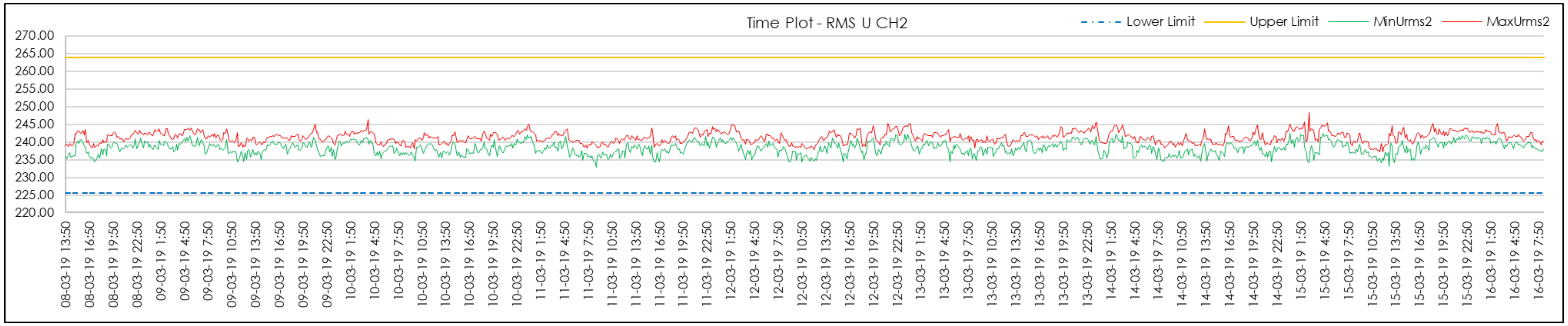

Figure 198 | STS4 Start Voltage measurements (White Phase)

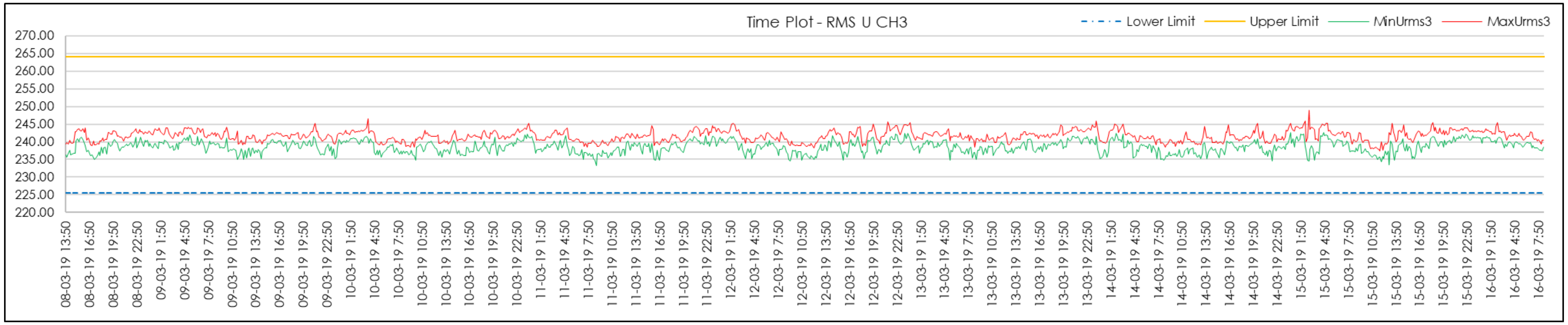

Figure 199 | STS4 Start Voltage measurements (Blue Phase)

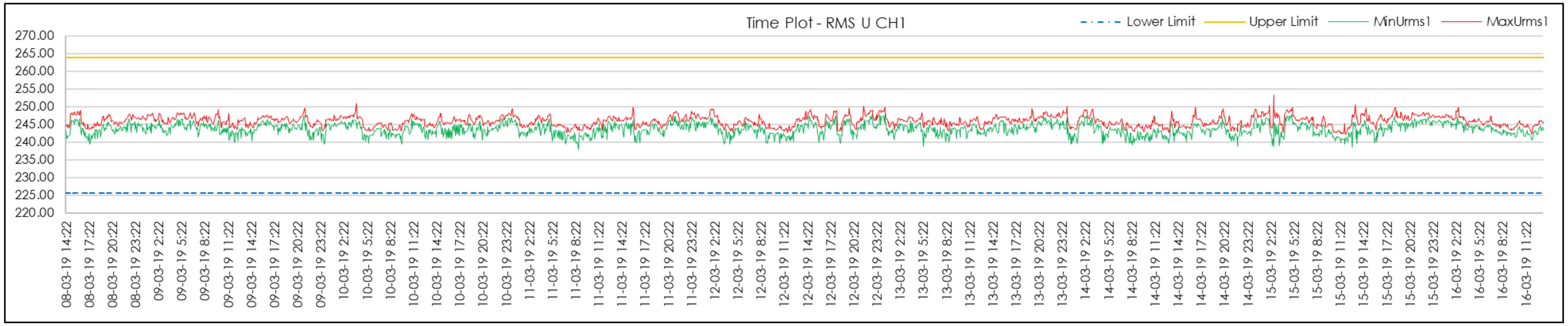

Figure 200 | STS4 End Voltage measurements (Red Phase)

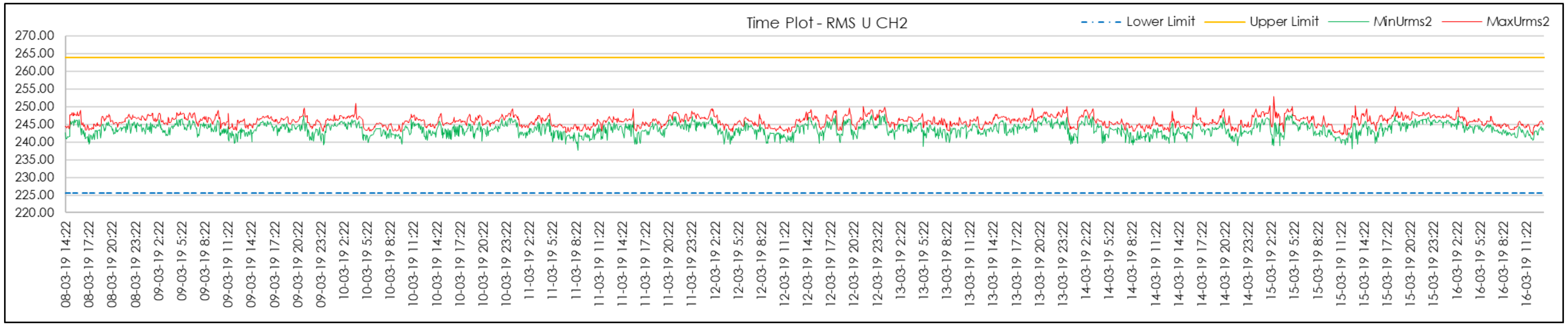

Figure 201 | STS4 End Voltage measurements (White Phase)

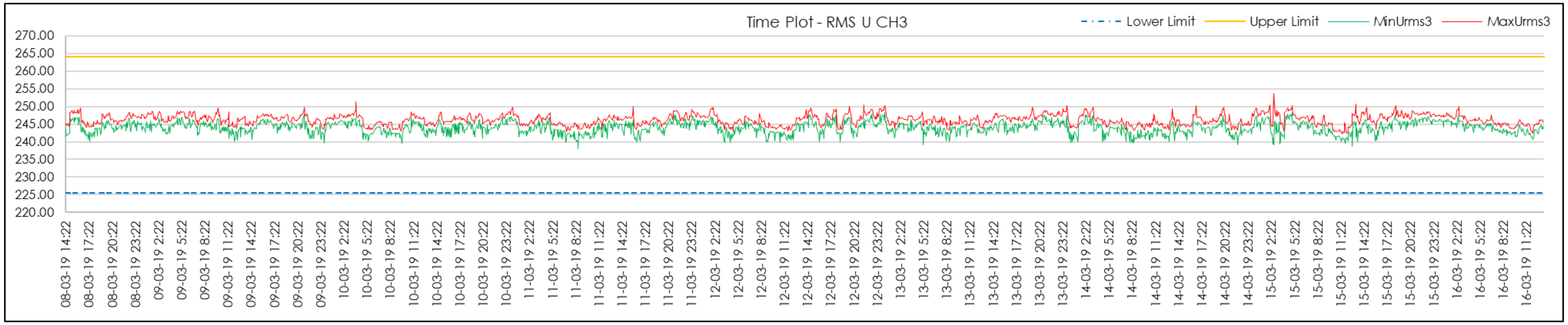

Figure 202 | STS4 End Voltage measurements (Blue Phase)

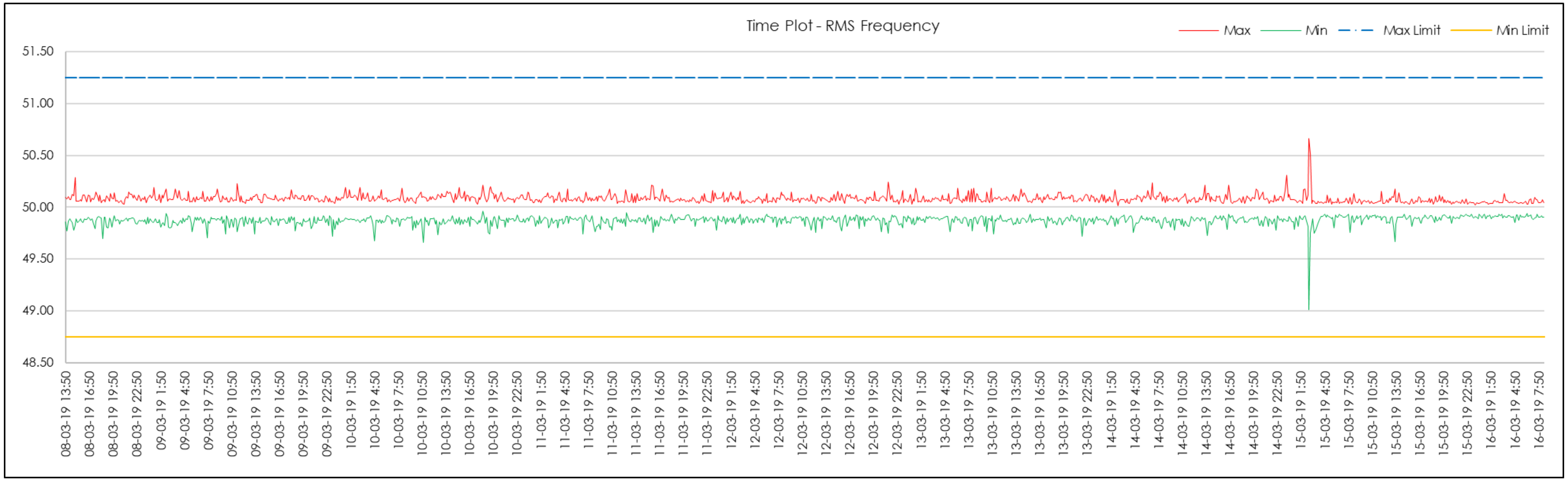

Figure 203 | STS4 Start Frequency measurements

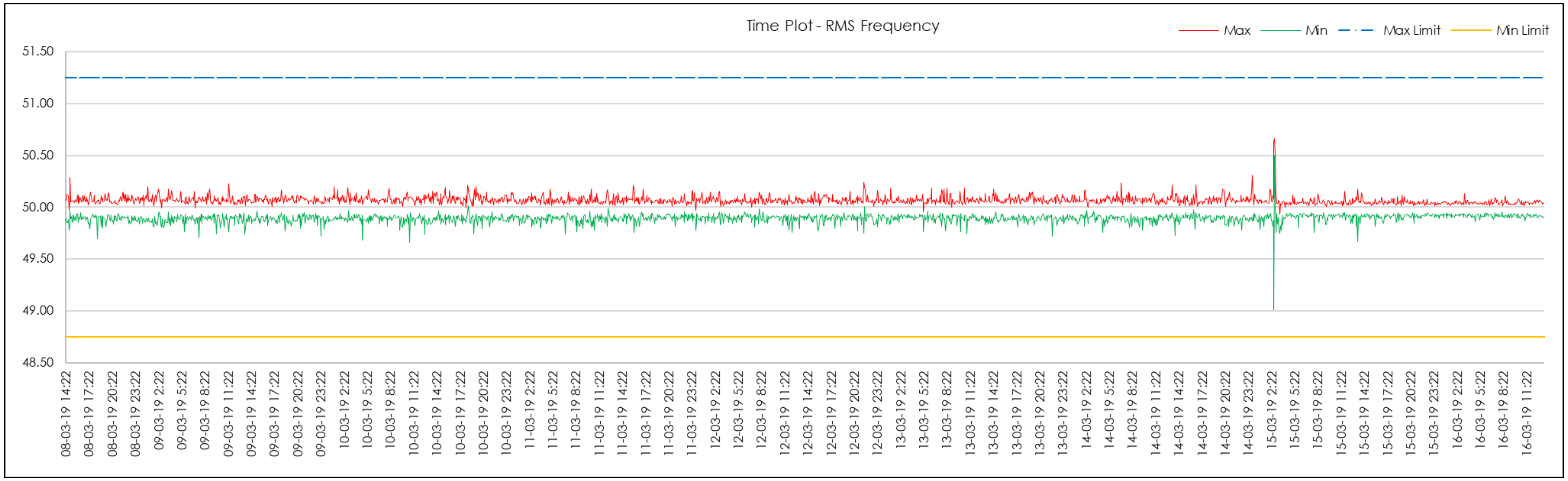

Figure 204 | STS4 End Frequency measurements

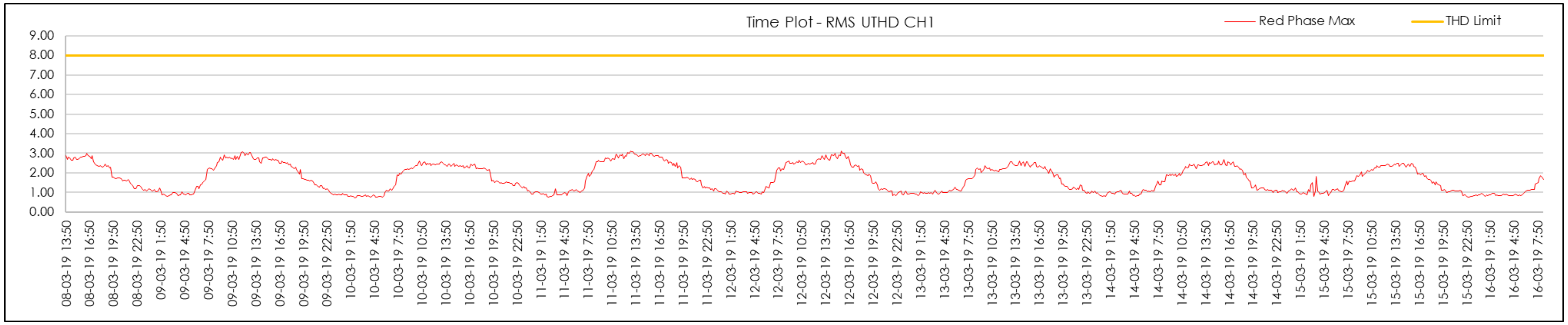

Figure 205 | STS4 Start U-THD measurements (Red Phase)

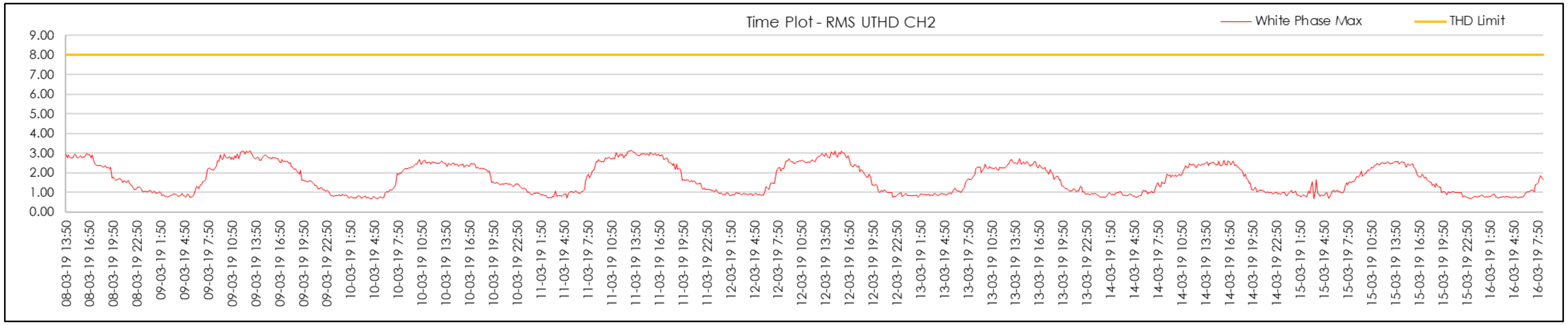

Figure 206 | STS4 Start U-THD measurements (White Phase)

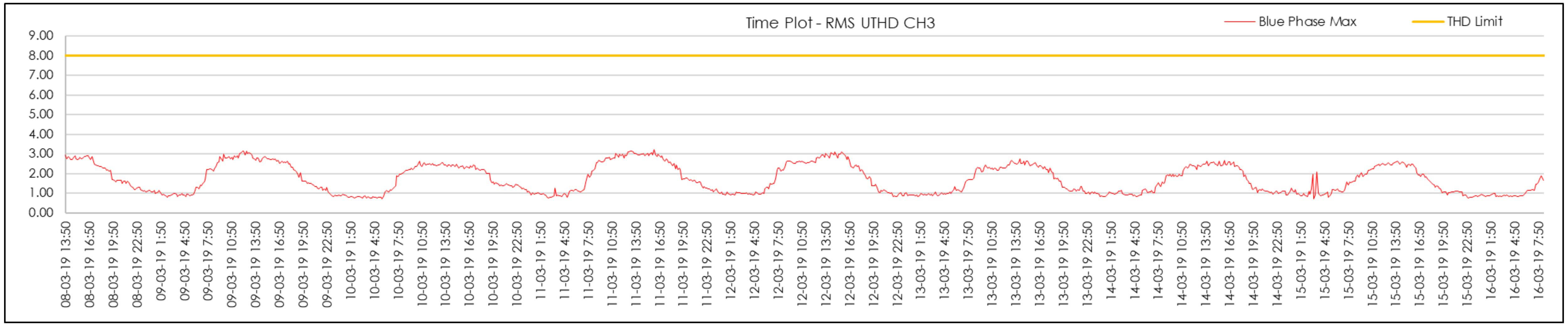

Figure 207 | STS4 Start U-THD measurements (Blue Phase)

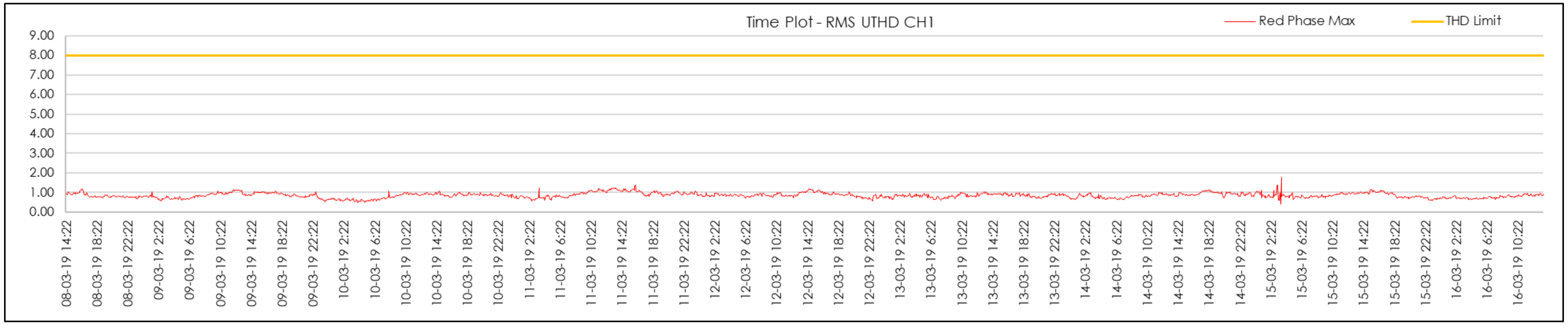

Figure 208 | STS4 End U-THD measurements (Red Phase)

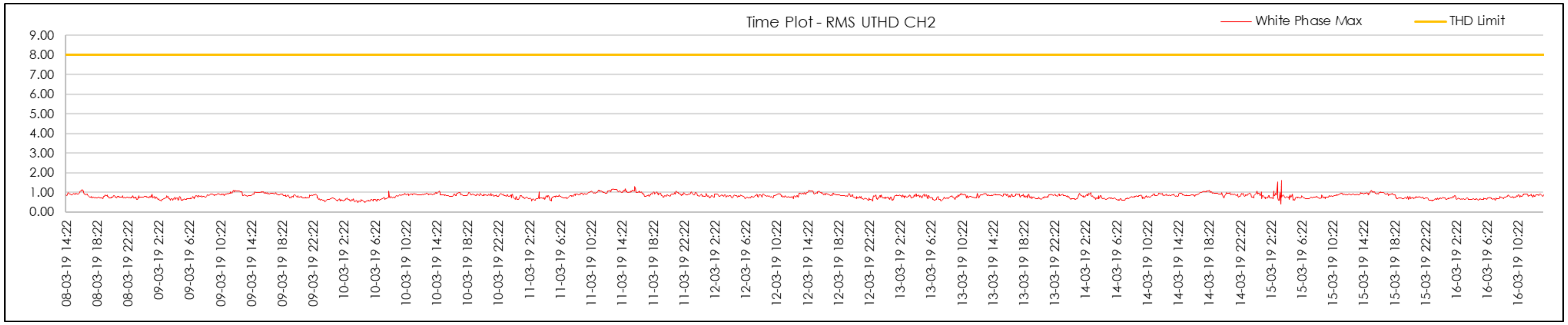

Figure 209 | STS4 End U-THD measurements (White Phase)

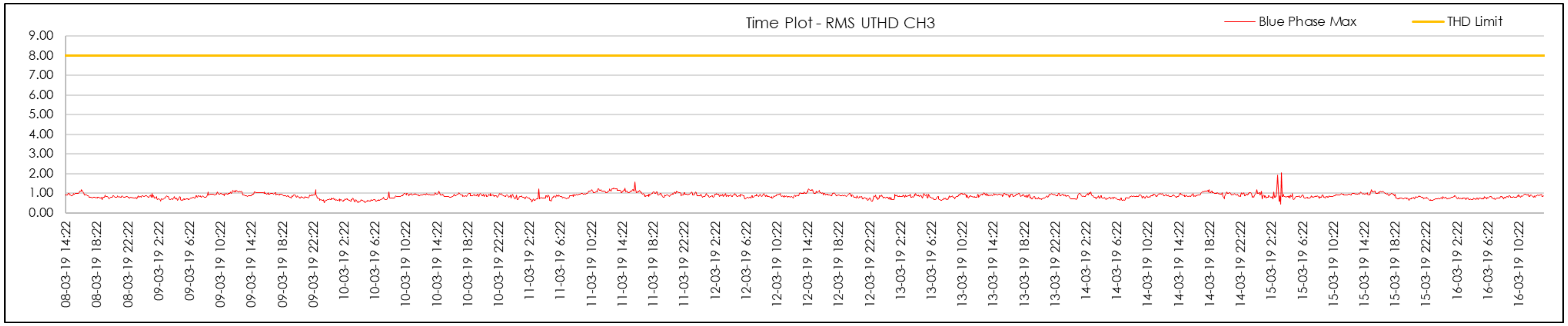

Figure 210 | STS4 End U-THD measurements (Blue Phase)

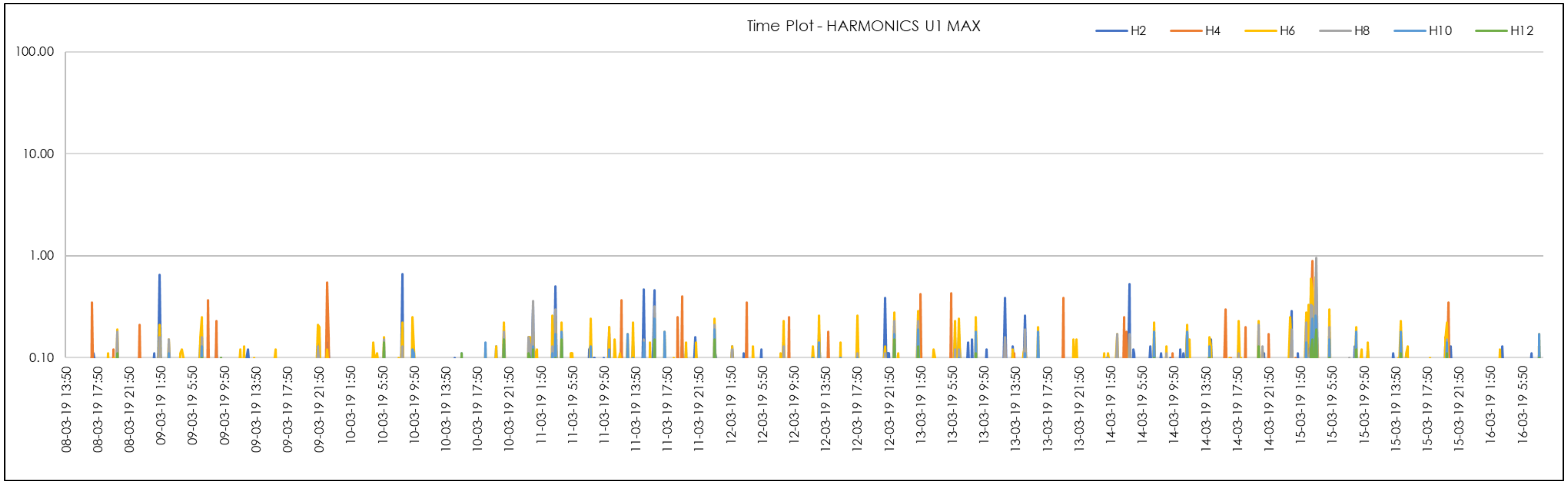

Figure 211 | STS4 Start Even 2nd-12th Harmonics (Red Phase)

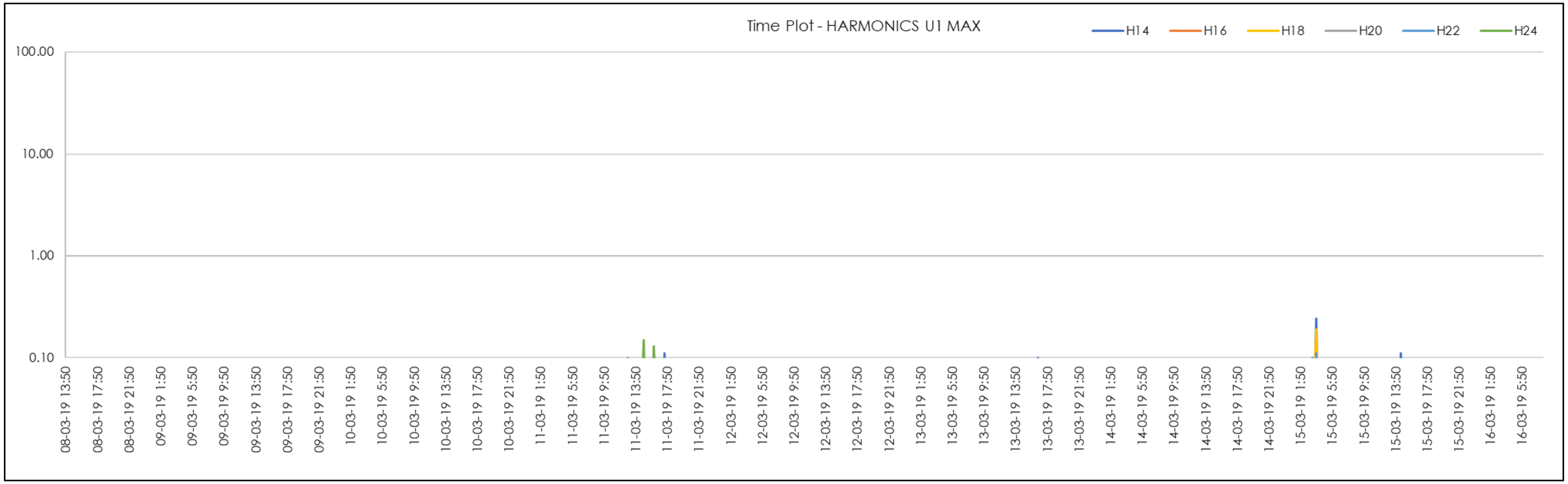

Figure 212 | STS4 Start Even 14th-24th Harmonics (Red Phase)

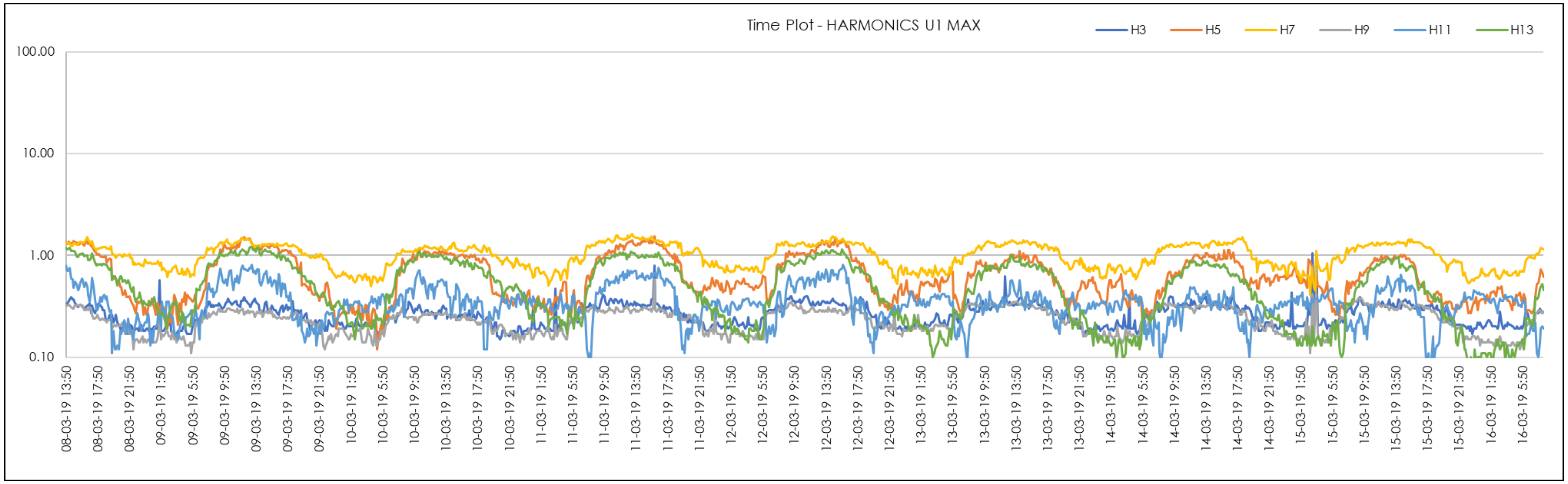

Figure 213 | STS4 Start Odd 3rd-13th Harmonics (Red Phase)

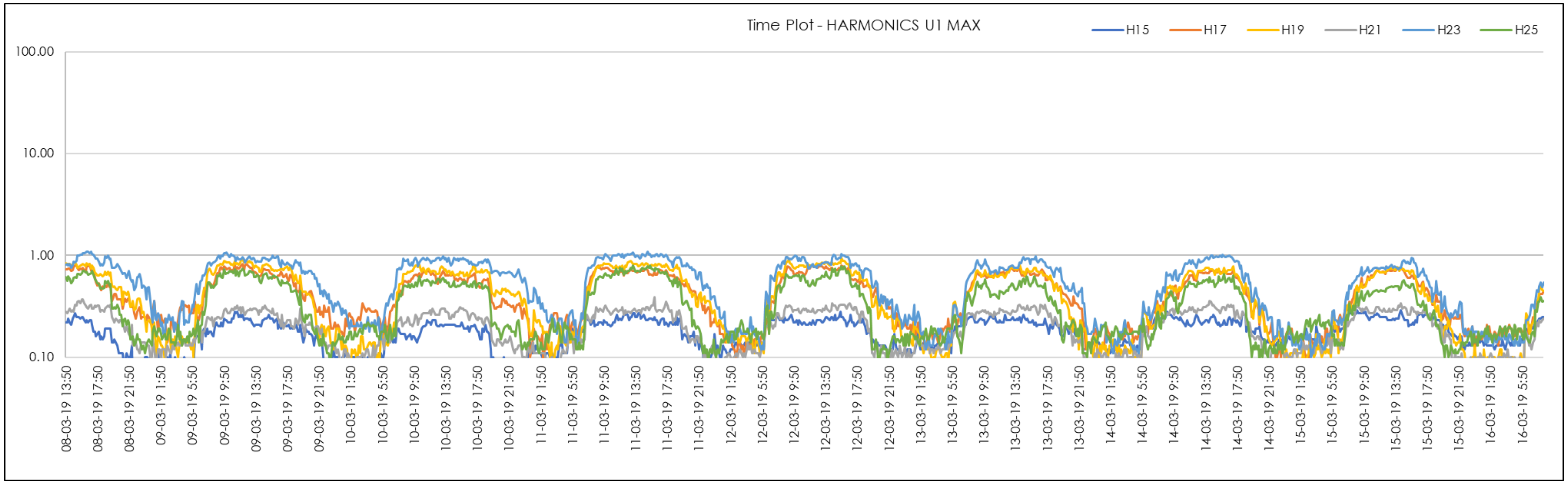

Figure 214 | STS4 Start Odd 15th-25th Harmonics (Red Phase)

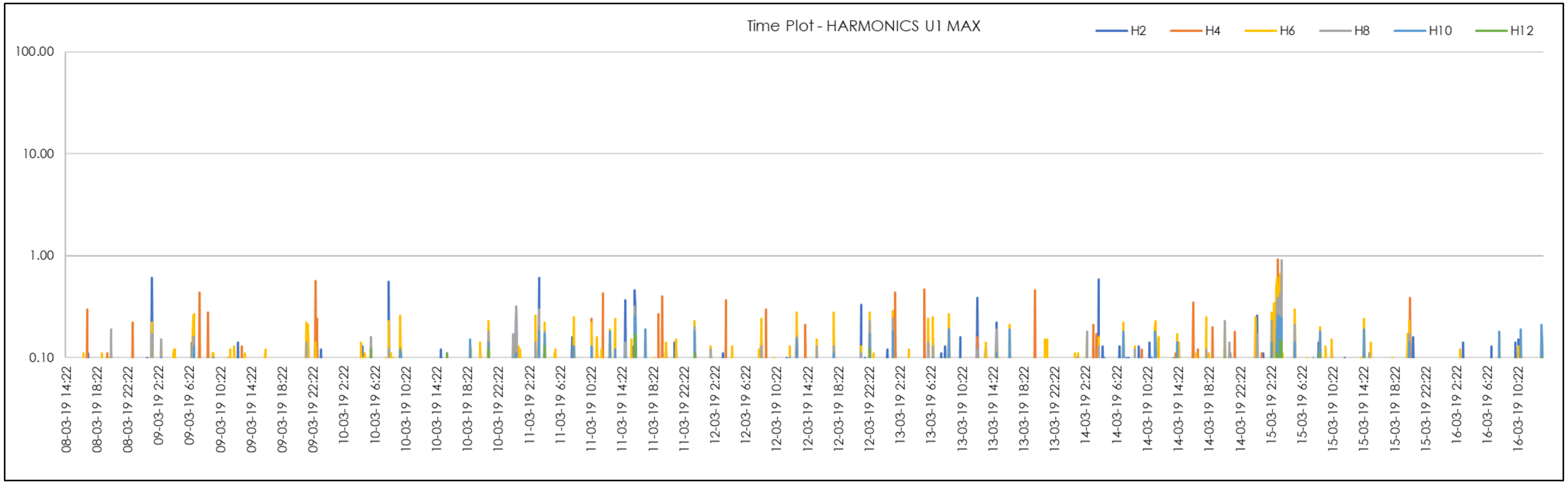

Figure 215 | STS4 End Even 2nd-12th Harmonics (Red Phase)

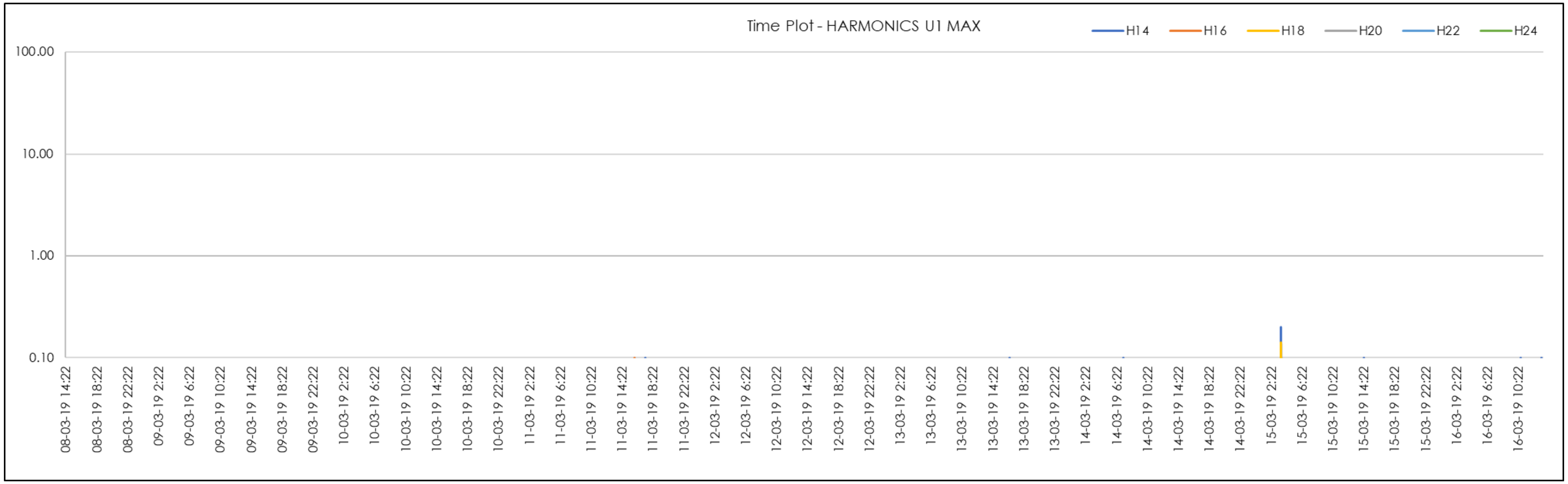

Figure 216 | STS4 End Even 14th-24th Harmonics (Red Phase)

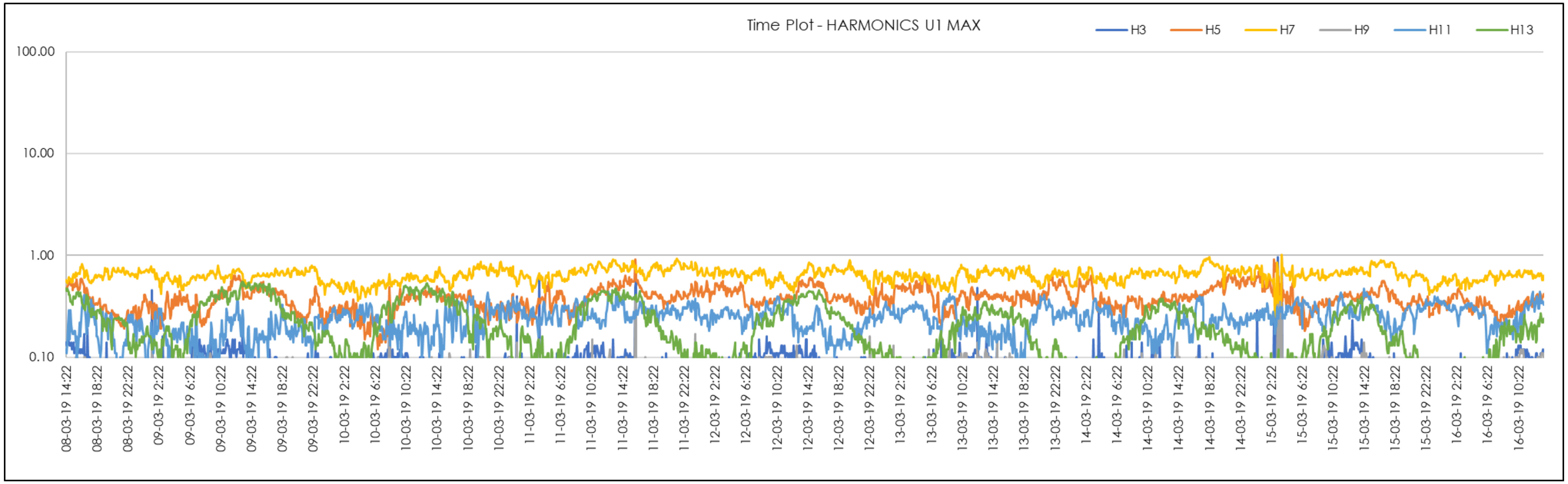

Figure 217 | STS4 End Odd 3rd-13th Harmonics (Red Phase)

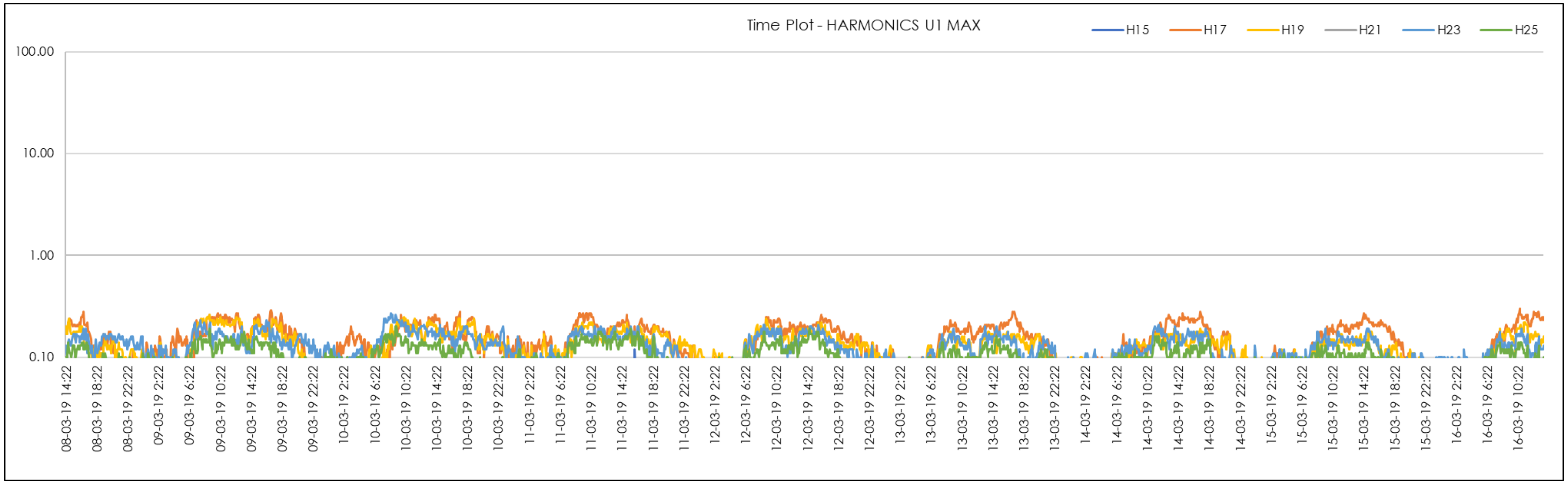

Figure 218 | STS4 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX B.8. FEEDER STS6 FLICKER, VOLTAGE, FREQUENCY AND HARMONICS

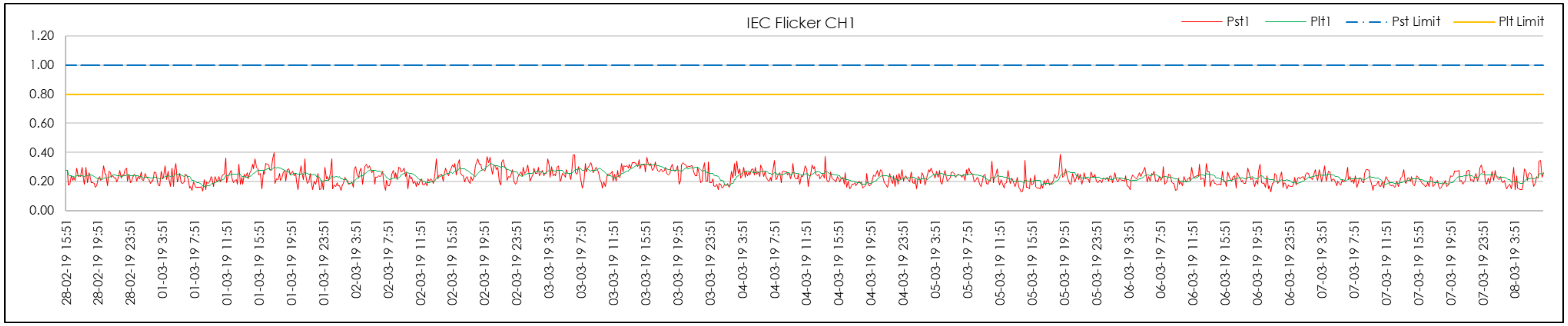

Figure 219 | STS6 Start Flicker measurements (Red Phase)

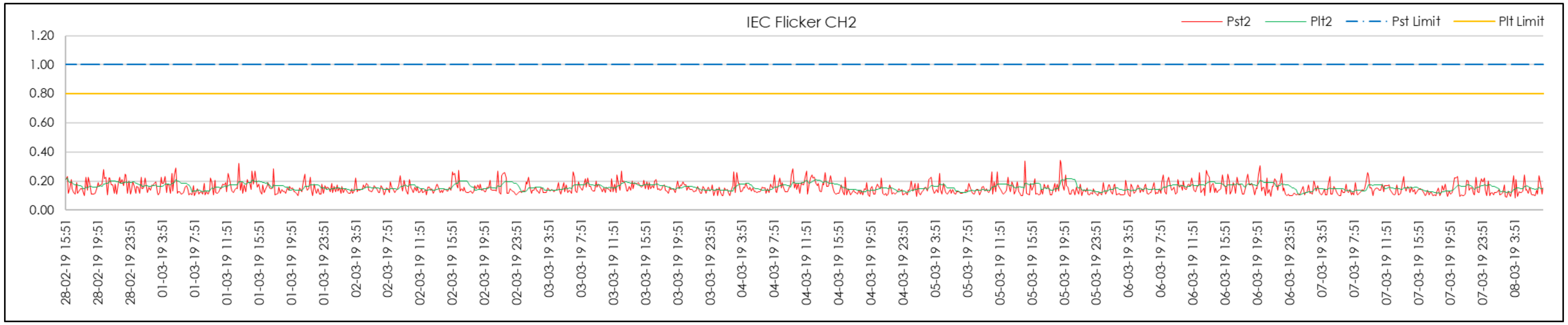

Figure 220 | STS6 Start Flicker measurements (White Phase)

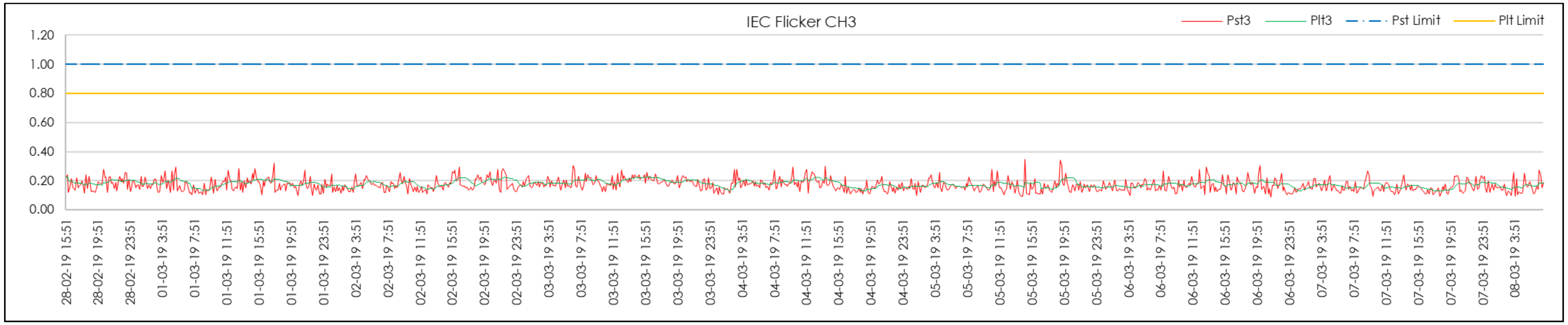

Figure 221 | STS6 Start Flicker measurements (Blue Phase)

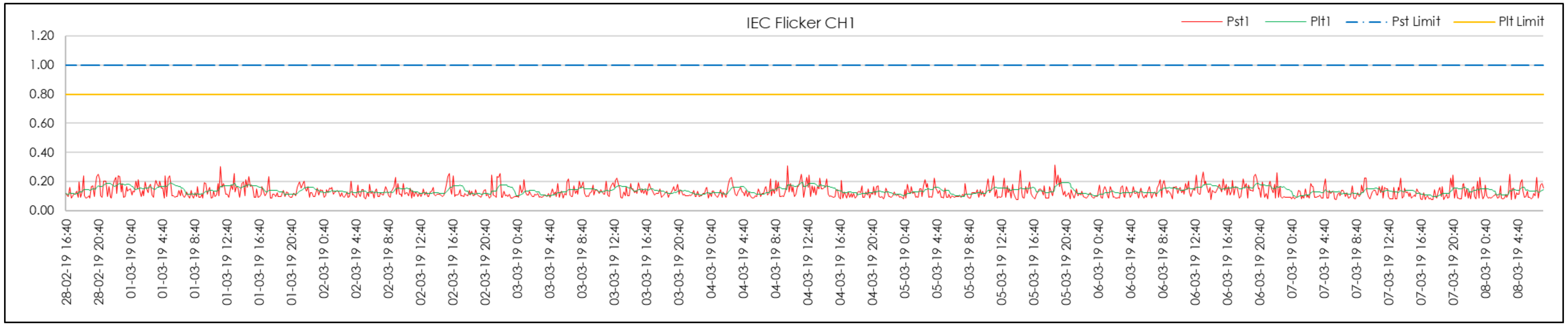

Figure 222 | STS6 End Flicker measurements (Red Phase)

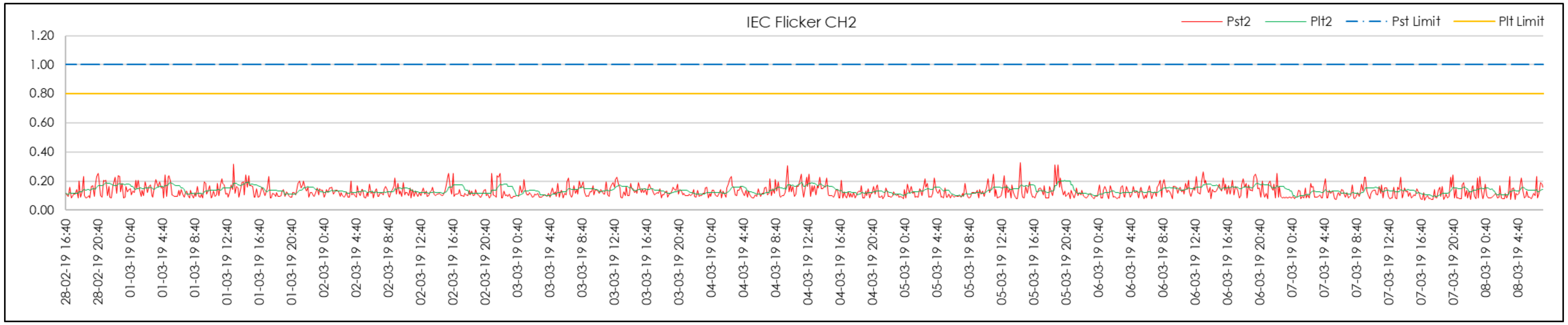

Figure 223 | STS6 End Flicker measurements (White Phase)

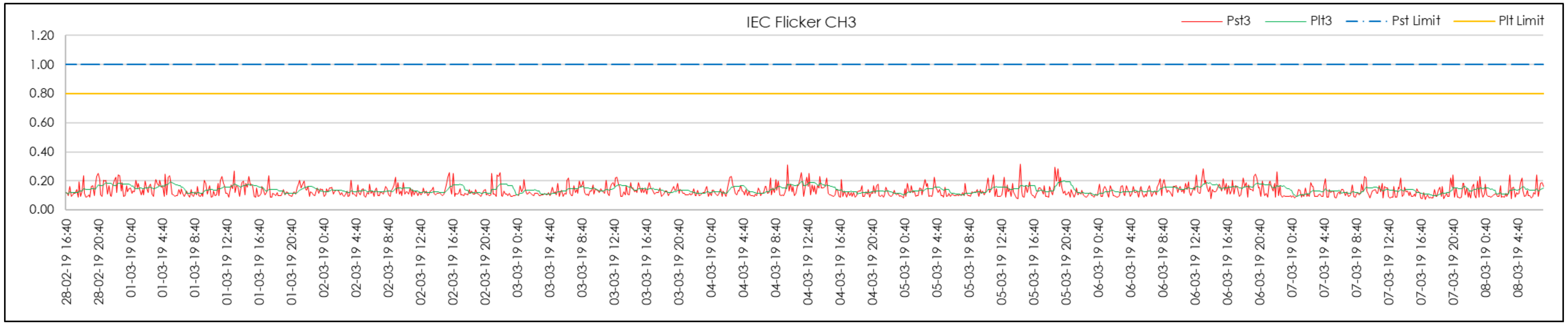

Figure 224 | STS6 End Flicker measurements (Blue Phase)

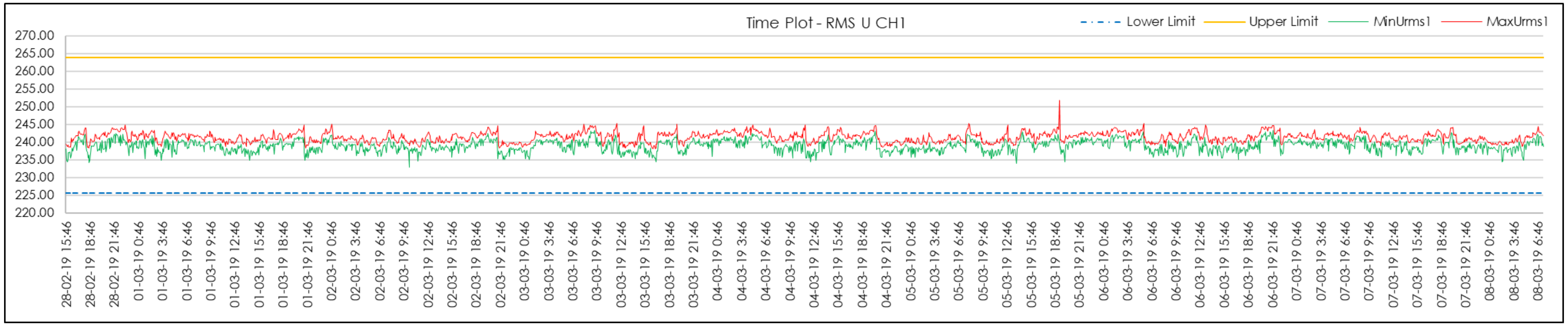

Figure 225 | STS6 Start Voltage measurements (Red Phase)

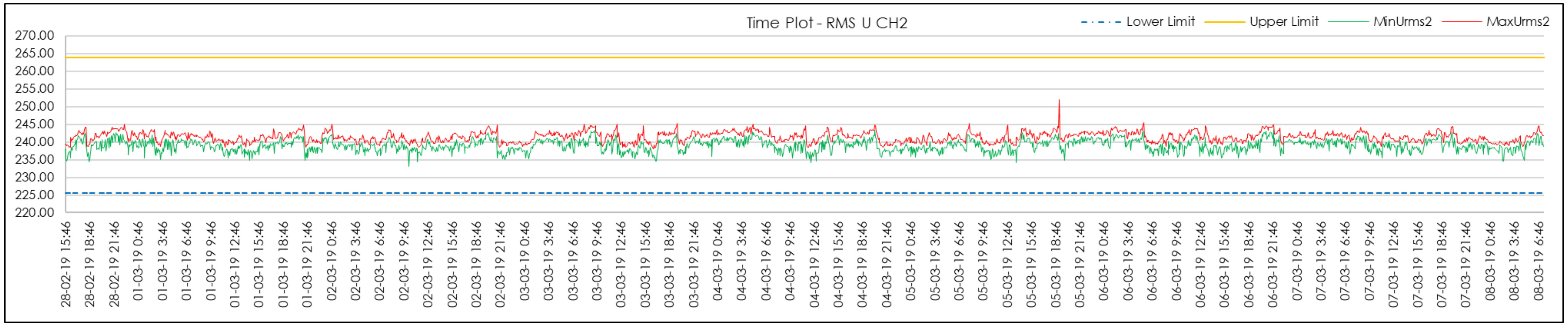

Figure 226 | STS6 Start Voltage measurements (White Phase)

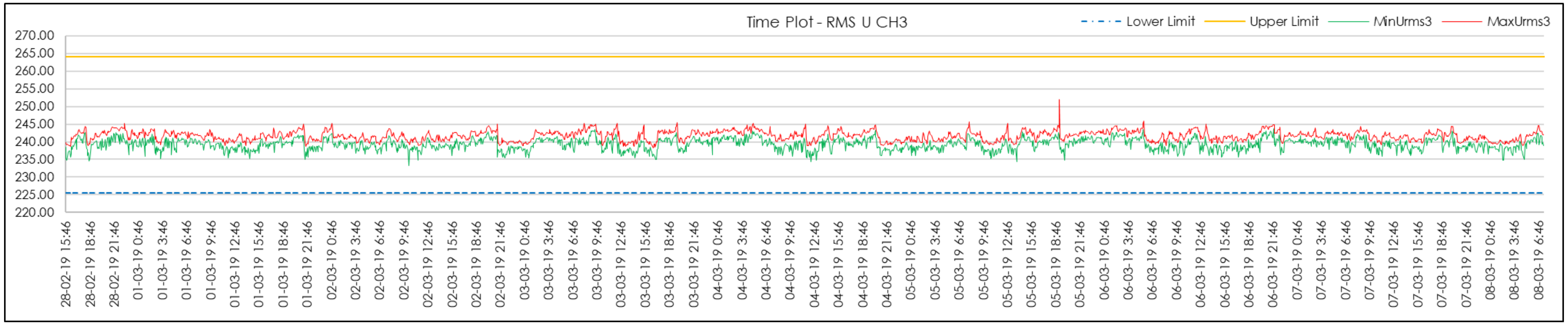

Figure 227 | STS6 Start Voltage measurements (Blue Phase)

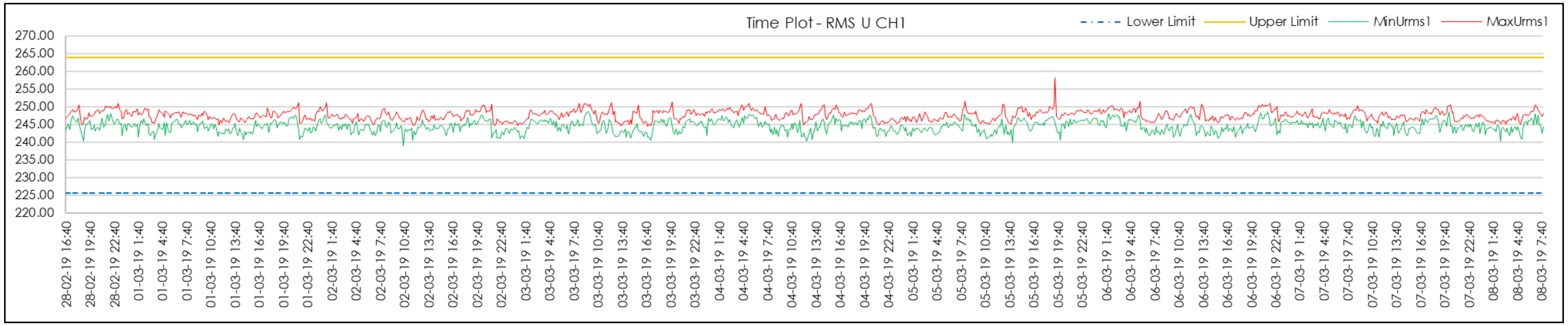

Figure 228 | STS6 End Voltage measurements (Red Phase)

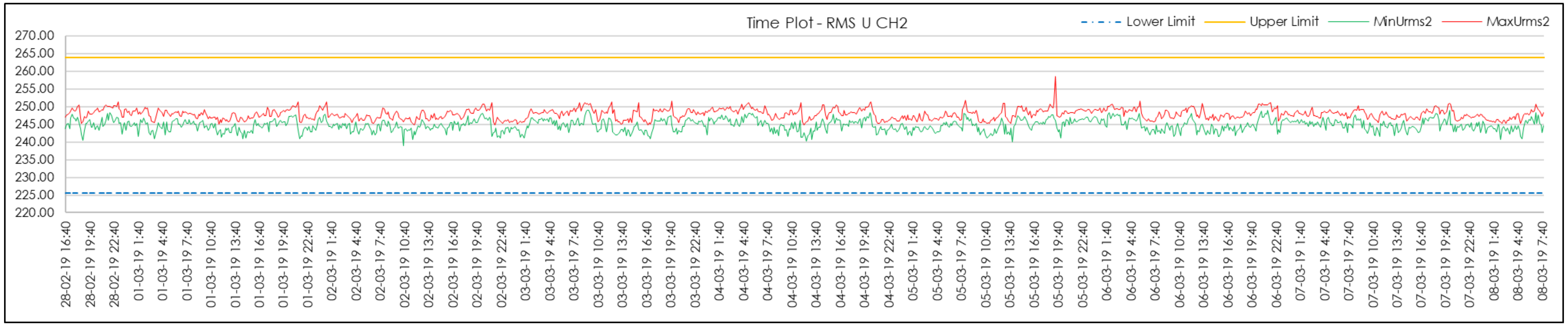

Figure 229 | STS6 End Voltage measurements (White Phase)

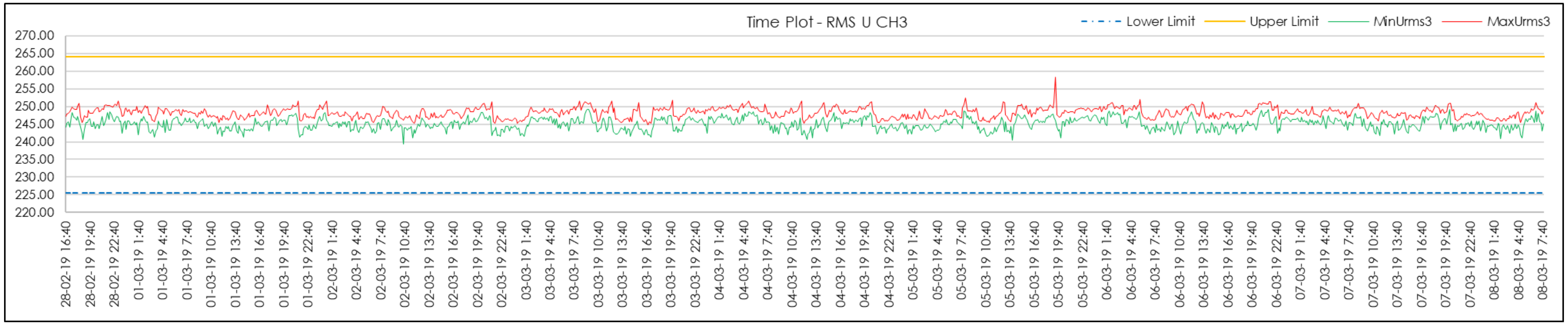

Figure 230 | STS6 End Voltage measurements (Blue Phase)

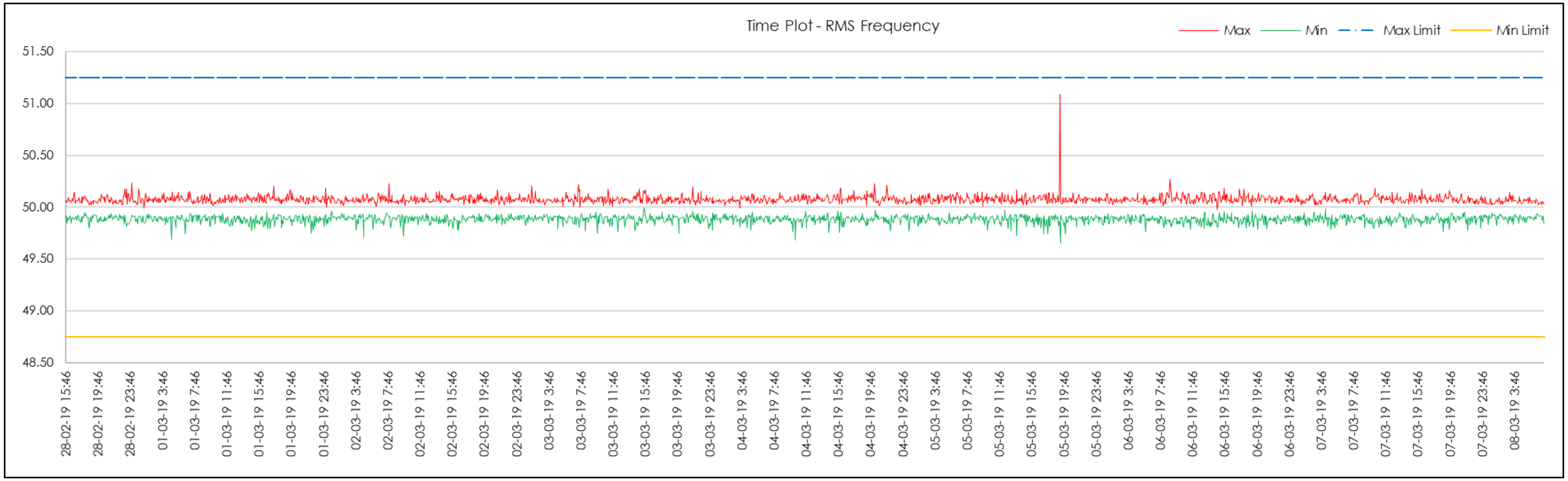

Figure 231 | STS6 Start Frequency measurements

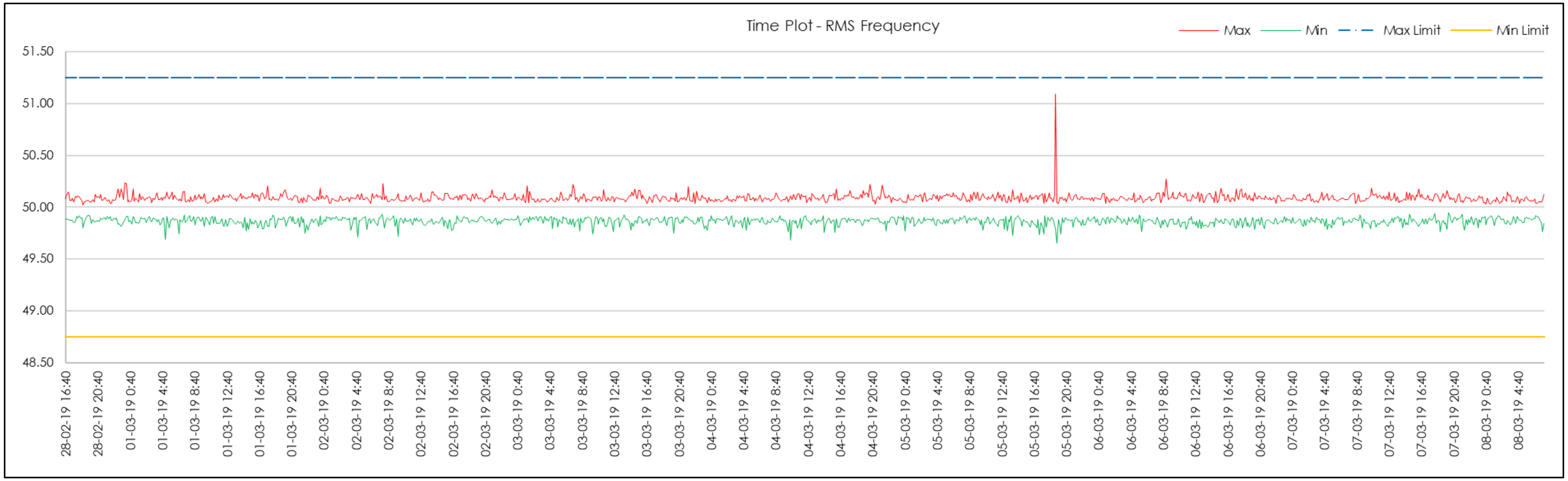

Figure 232 | STS6 End Frequency measurements

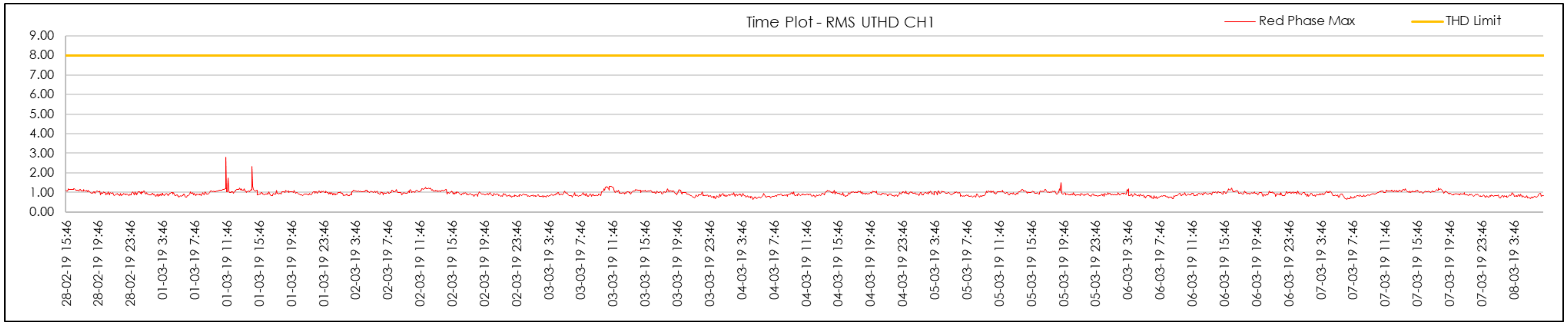

Figure 233 | STS6 Start U-THD measurements (Red Phase)

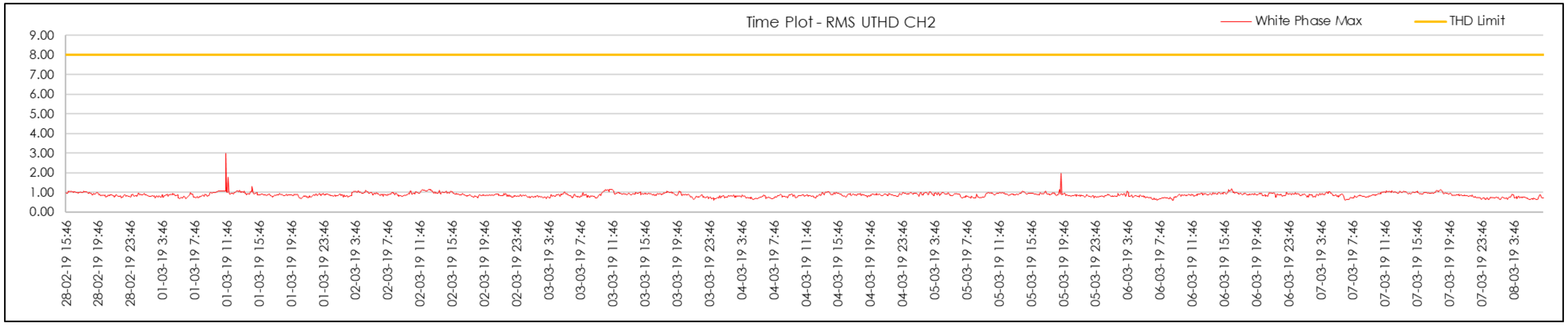

Figure 234 | STS6 Start U-THD measurements (White Phase)

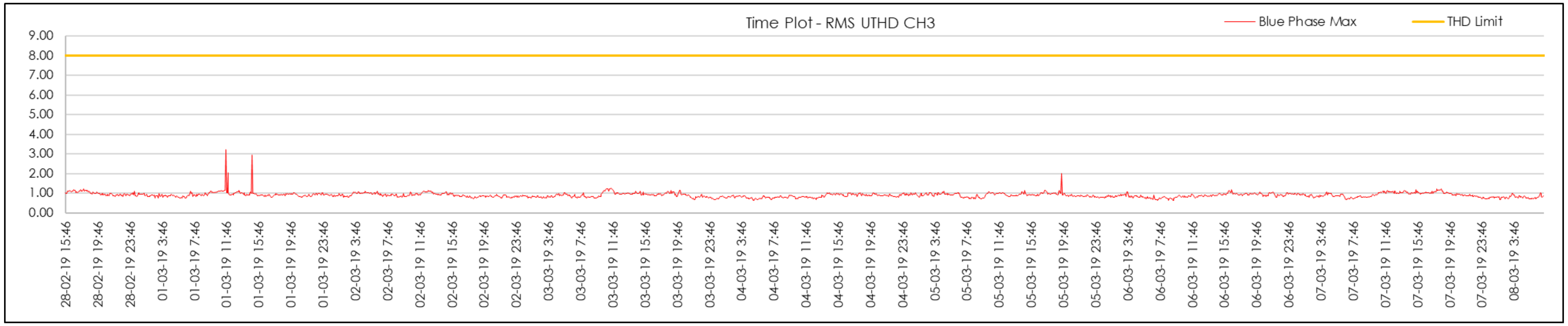

Figure 235 | STS6 Start U-THD measurements (Blue Phase)

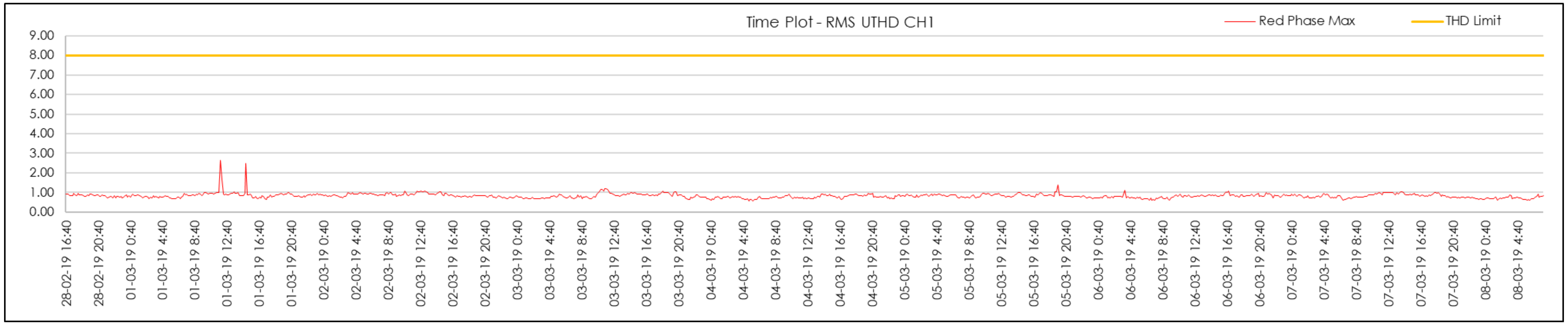

Figure 236 | STS6 End U-THD measurements (Red Phase)

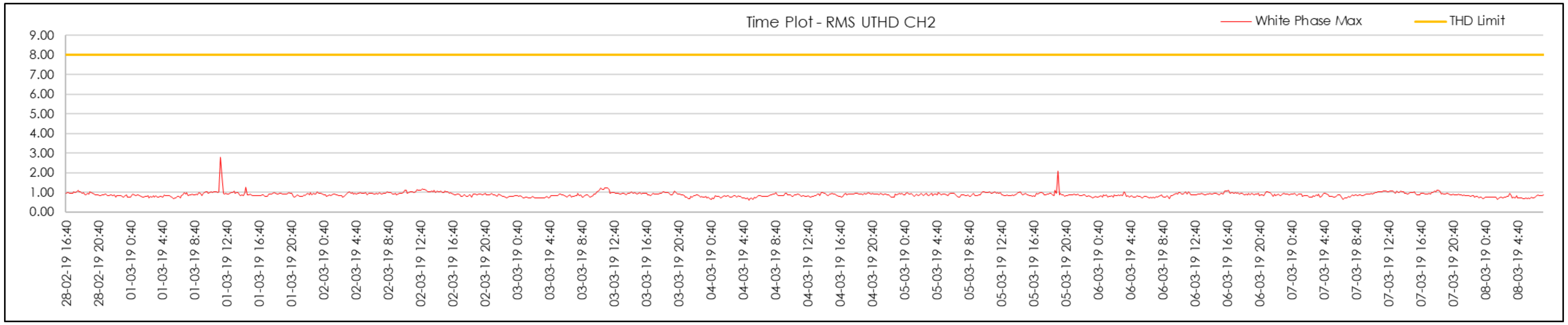

Figure 237 | STS6 End U-THD measurements (White Phase)

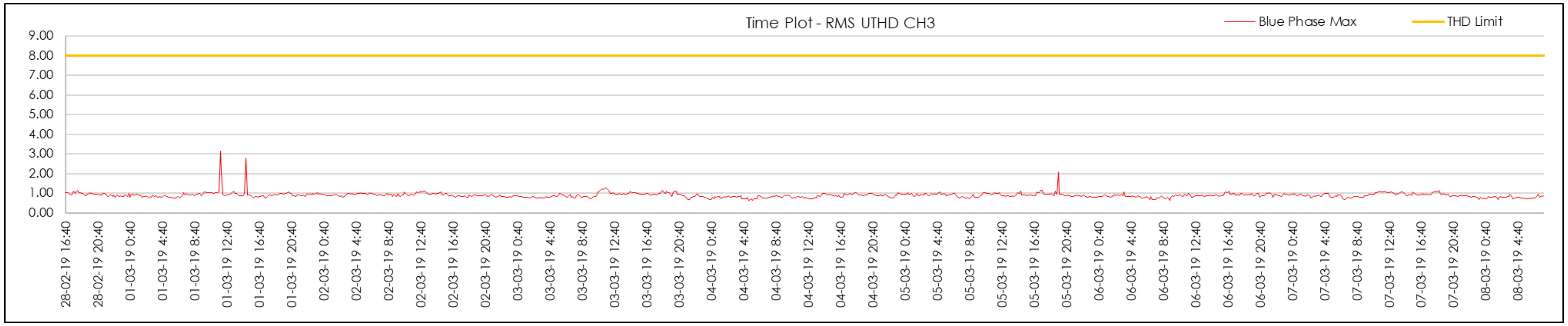

Figure 238 | STS6 End U-THD measurements (Blue Phase)

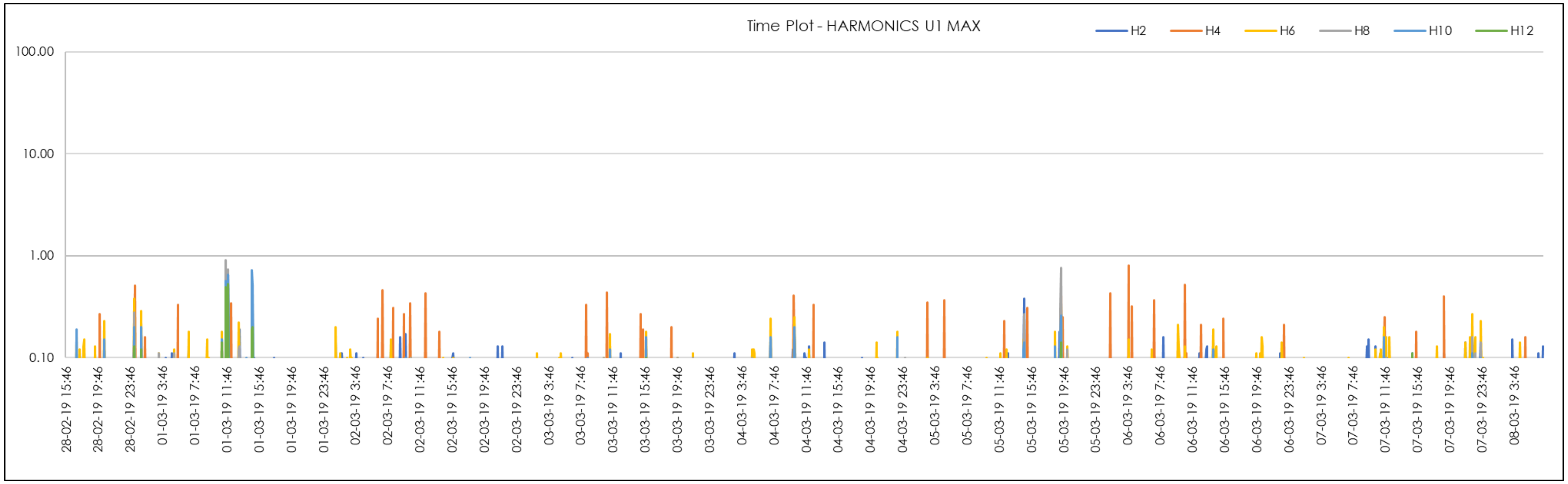

Figure 239 | STS6 Start Even 2nd-12th Harmonics (Red Phase)

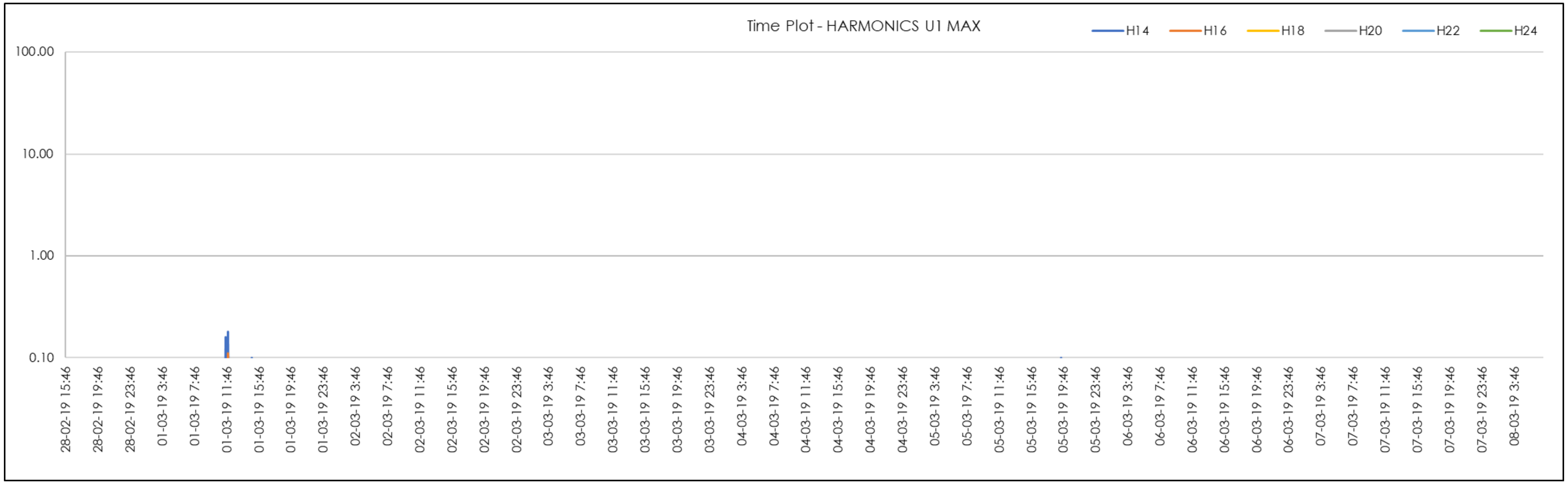

Figure 240 | STS6 Start Even 14th-24th Harmonics (Red Phase)

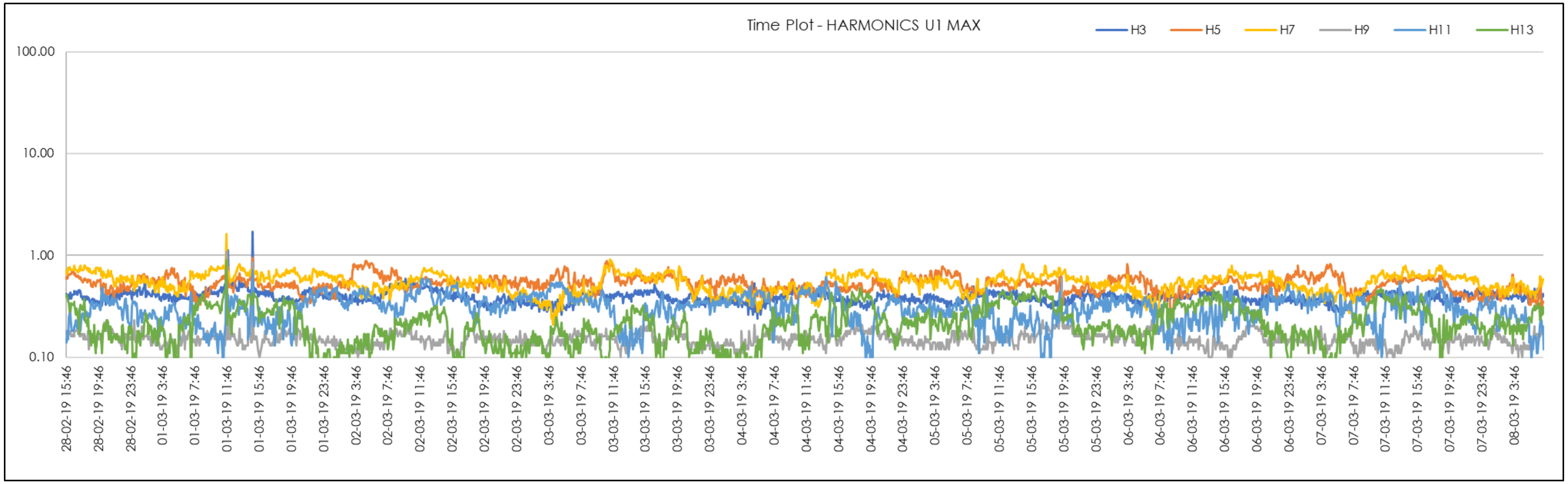

Figure 241 | STS6 Start Odd 3rd-13th Harmonics (Red Phase)

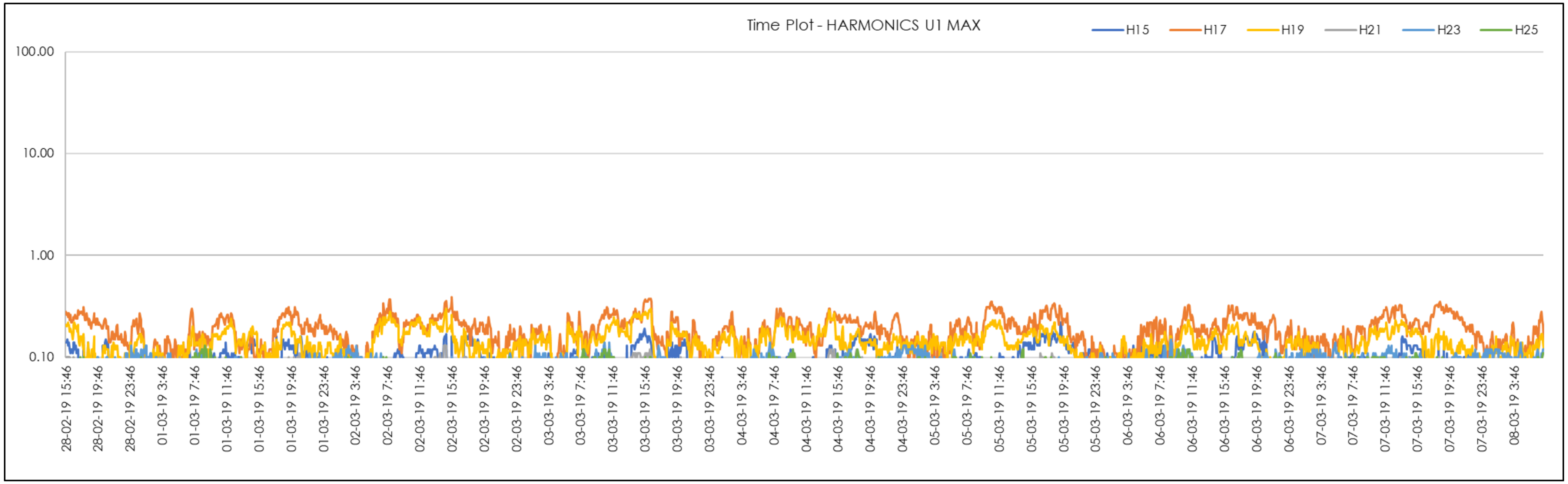

Figure 242 | STS6 Start Odd 15th-25th Harmonics (Red Phase)

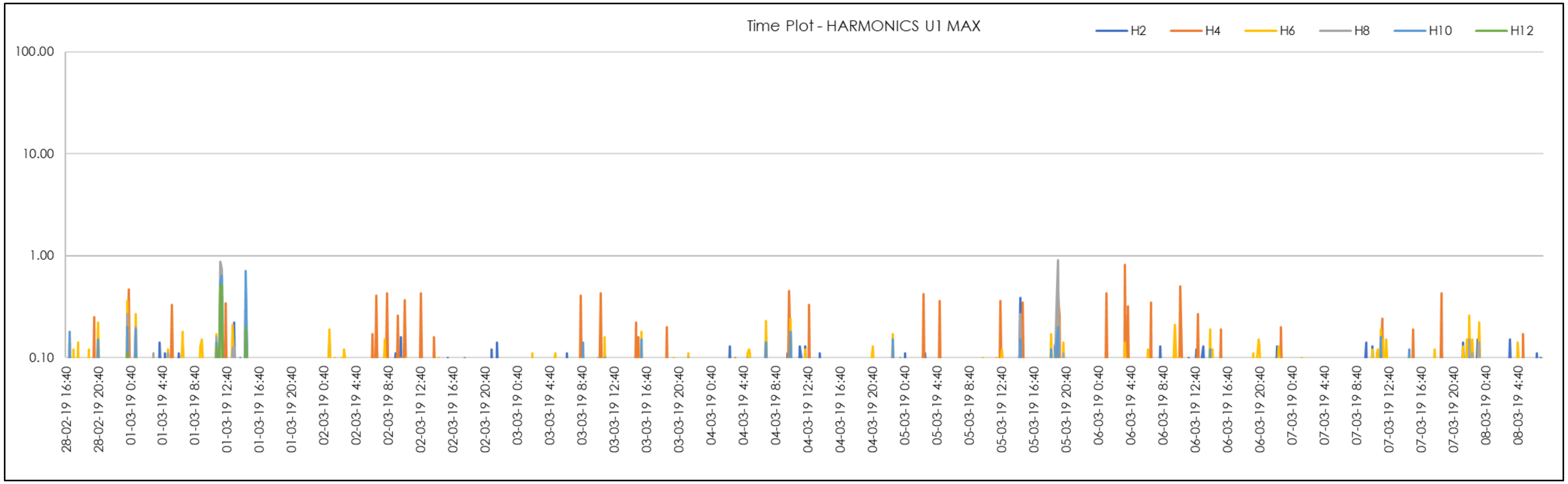

Figure 243 | **STS6 End Even 2nd-12th Harmonics (Red Phase)**

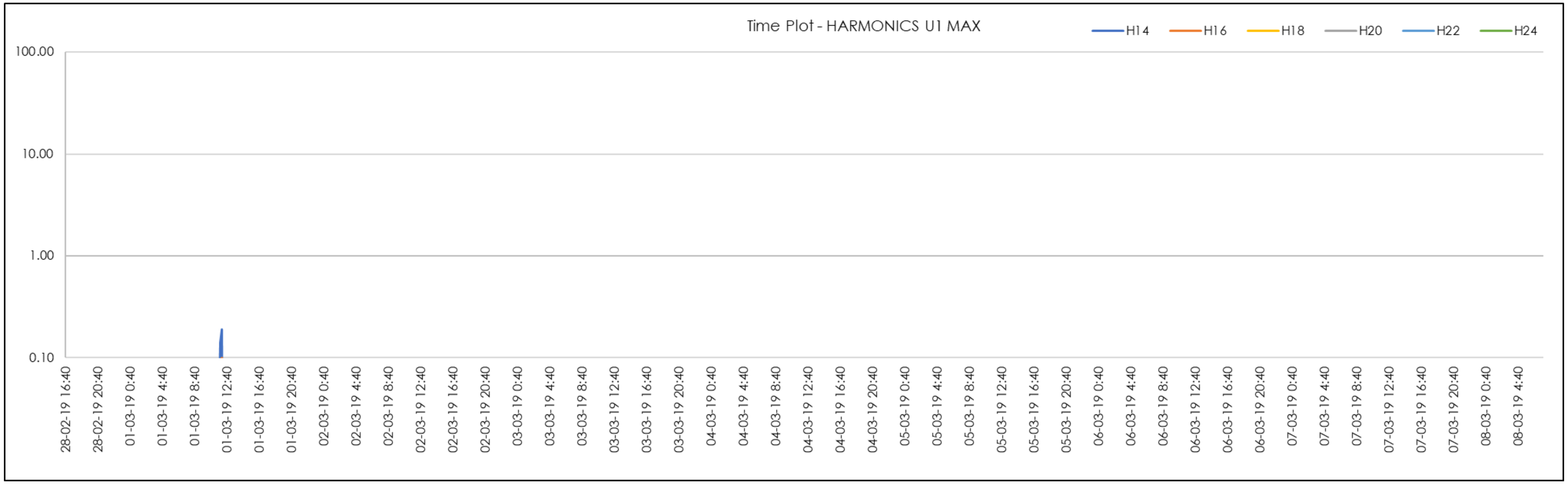

Figure 244 | **STS6 End Even 14th-24th Harmonics (Red Phase)**

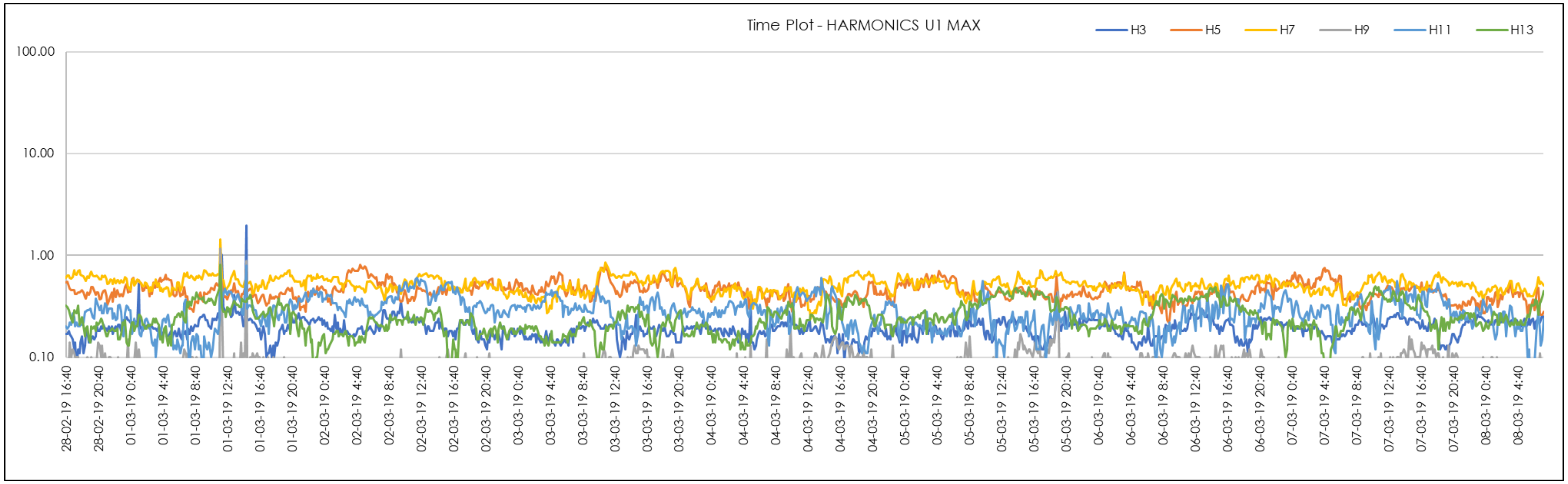

Figure 245 | STS6 End Odd 3rd-13th Harmonics (Red Phase)

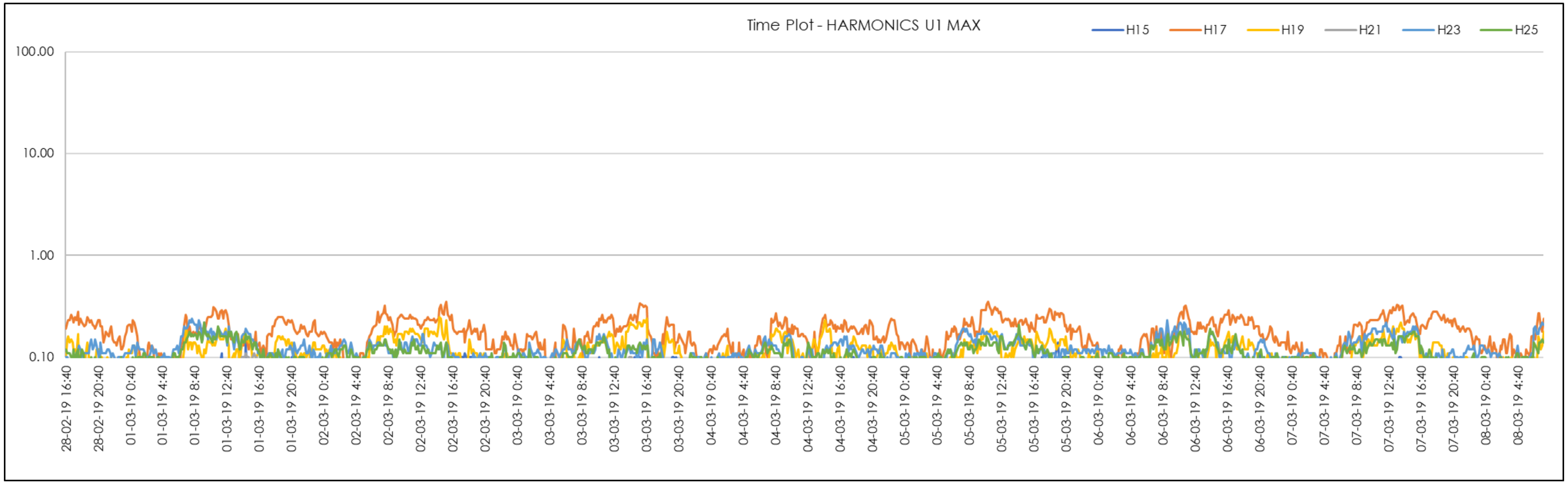

Figure 246 | STS6 End Odd 15th-25th Harmonics (Red Phase)

APPENDIX C. ELEC. FAULT LOGS (2018/2019 FY)

Event	Notification Number (1SAP)	Date	Outage Duration (mins)	Affected Generation/Fdr/Distribution Description	System Voltage kV	Circuit-Breaker/Fuse that cleared the fault	Effect on operations	Substation	Customers Affected	Feeder	Customers Affected	TX/RMU/REC	Customers Affected	Total Consumers affected
364	423830238	2019-06-15	148.55	TC3 Feeder	11	Town RMU01	RMU01 Tripped on Earth Fault causing loss of supply to majority of TC3's Load		0	RMU01 TC3	457		0	457
353		2019-03-02	71.00	Town PS78	0.415	Town PS78	Services in New LIA		0		0	ps78	2	2
347	422834374	2019-02-19	50.00	Town South Town Sub	11	N/A	Loss of Supply to STS's loads, half of Newman Town	**Southtown**	791		0		0	791
346	422822563	2019-02-18	96.00	Newman PS34 High School Feeder	0.415	Town PS34	Gregory Ave High School main supply tripped out		0		0	ps34	2	2
330	421667752	2018-11-03	44.00	South and East Newman	11	Town Fdr TC1	Loss of supply to South and East Newman		0	TC1	400		0	400
328		2018-10-29	109.00	Whole Town Outage	11		Whole Town outage	**Whole Town Outage**	2501		0		0	2501
322	433496239	2018-09-20	217.00	Whole Town outage	33	N/A	Whole Town Blackout	**Whole Town Outage**	2501		0		0	2501