Disturbance Analysis

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Manager, Reliability & Protection

Content:

- COMTRADE file Format
- Fault Distance calculation
- Time Adjustment
- New channel building
- Harmonics
- Build SOE from digital status
- A/R from one end and tripping from other end with L/R- different scenario
- Identify Sending and Receiving end
- Slow fault mechanism
  - Vegetation
  - Solid fault
- Lightening fault
- Broken conductor
- Generator
- Transformer differential
- RE

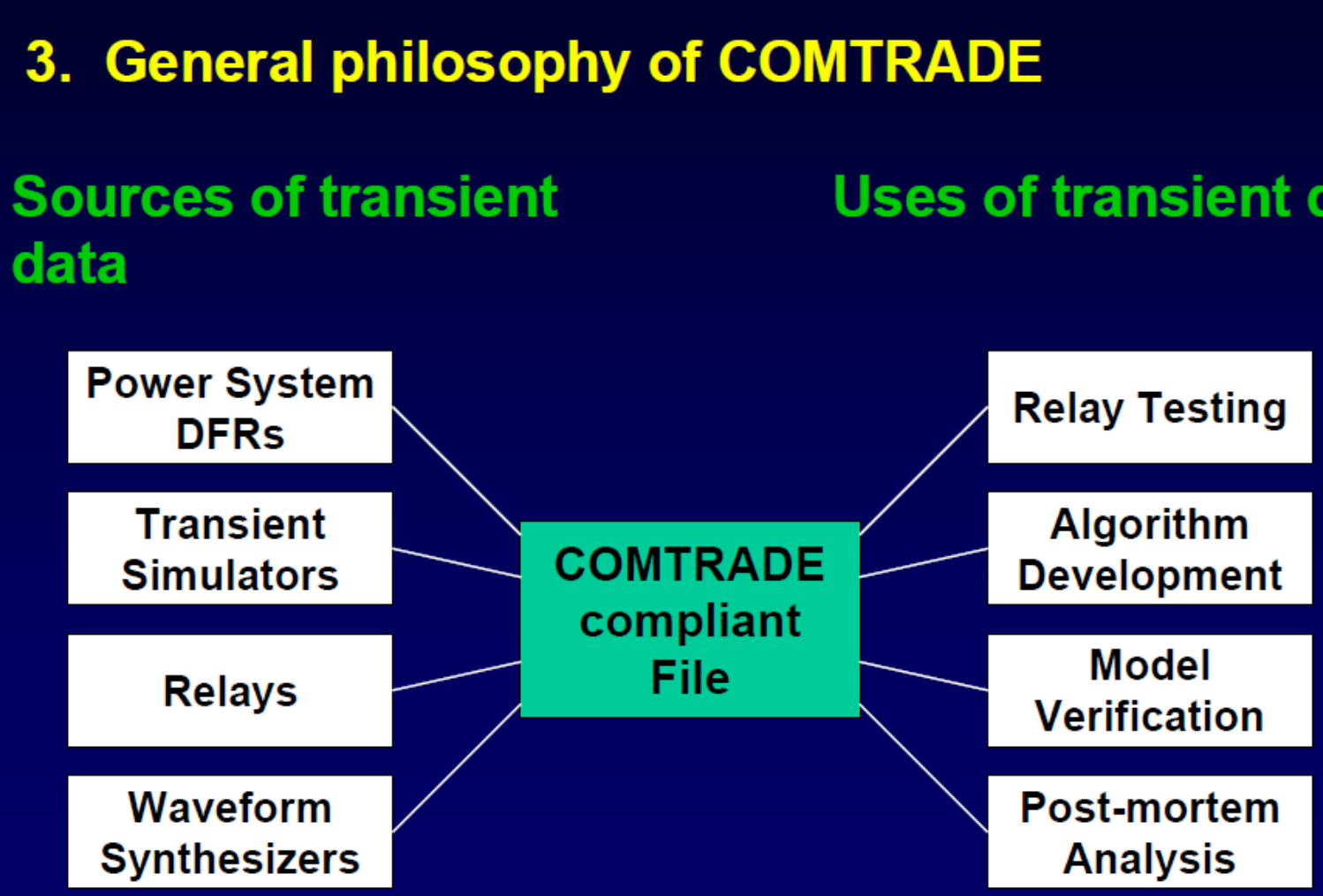
COMTRADE

1. Historical Background
   - -CIGRE WG 34.01, A.G. Phadke, Convener
   - -Scope of WG Report
   - -CIGRE and standards
   - -Genesis of COMTRADE

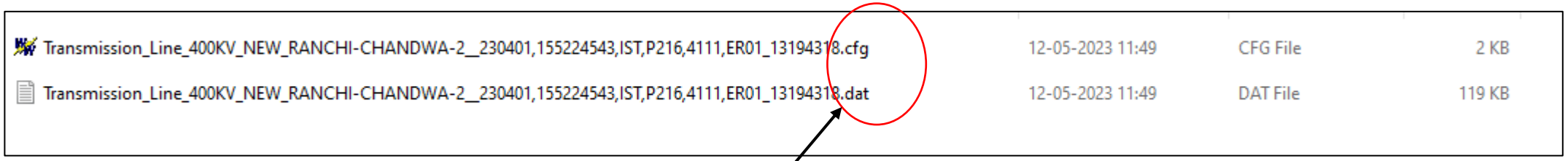
2. IEEE Working Group PSRC H-5
   - -Formed in 1988-89
   - -Common membership and Chair with CIGRE 34.01
   - -Assignment: to create an IEEE Standard

COMTRADE

3. General philosophy of COMTRADE



File Type and Description



Mainly Tw file is required for complete analysis

1. CFG-CONFIGURATION FILE

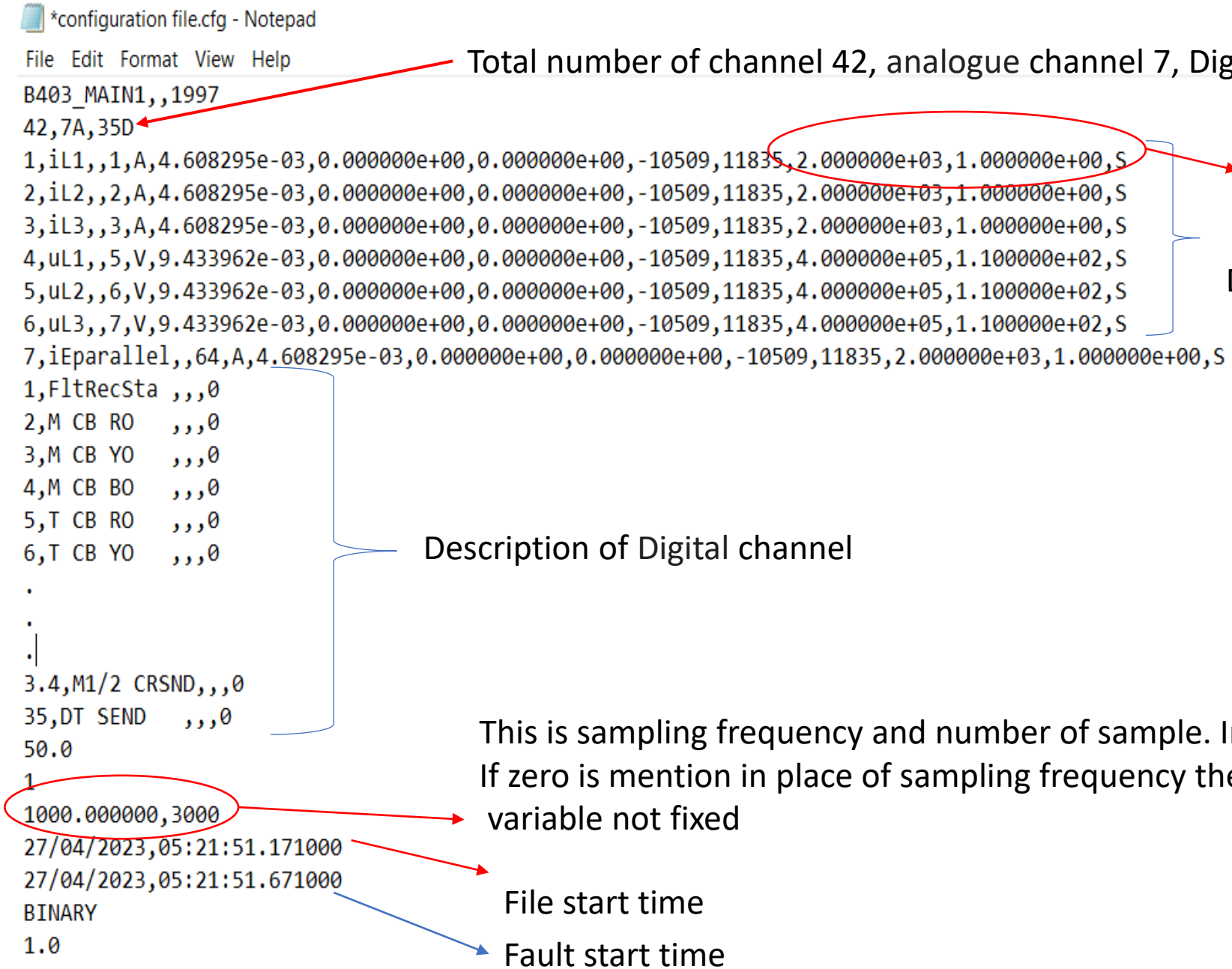
a. Station name and identification
b. Number and type of channels
c. Channel names, units, and conversion factors
d. Line frequency
e. Sample rate and number of samples at this rate
f. Date and time of first data value
g. Date and time of trigger point
h. File type

2. Dat-DATA FILE

Arranged in rows and columns Each row contains one sample point Each row contains n plus 2 entries
As many rows as needed First column is integer sample number Second column is sample time in µsec
All other columns contain sample values All data values are integers An ASCII end of file mark at the end

CONFIGURATION FILE (REVISED COMTRADE)

```
station_name,rec_dev,rev_year<CR/LF>
NGC-1                ,                      ,1997
TT,##A,##D<CR/LF>
 55,23A, 32D
An,ch_id,ph,ccbm,uu,a,b,skew,min,max,primary,secondary,PS<CR/LF>
  1,F1-IA              ,A,,A     ,     0.001953,0,0,-32767,32767,   2000.0,  1.0,S
  2,F2-IB              ,B,,A     ,     0.001953,0,0,-32767,32767,   2000.0,  1.0,S
  3,F3-IC              ,C,,A     ,     0.001953,0,0,-32767,32767,   2000.0,  1.0,S
   .
Dn,ch_id,ph,ccbm,y<CR/LF>
  1,Virt Op 2    On      ,,,0
  2,PH DIST Z1 OP        ,,,0
   .
 32,Off                  ,,,0
lf<CR/LF>
 50
nrates<CR/LF>
 0
samp,endsamp<CR/LF>
 0,  5680
dd/mm/yyyy,hh:mm:ss.ssssss<CR/LF>
 01/08/2012,06:11:16.003865
dd/mm/yyyy,hh:mm:ss.ssssss<CR/LF>
 01/08/2012,06:11:16.713704
ft<CR/LF>
 BINARY
timemult<CR/LF>
 0.25
```


*configuration file.cfg - Notepad
File Edit Format View Help
B403_MAIN1,,1997
42,7A,35D
1,iL1,,1,A,4.608295e-03,0.000000e+00,0.000000e+00,-10509,11835,2.000000e+03,1.000000e+00,S
2,iL2,,2,A,4.608295e-03,0.000000e+00,0.000000e+00,-10509,11835,2.000000e+03,1.000000e+00,S
3,iL3,,3,A,4.608295e-03,0.000000e+00,0.000000e+00,-10509,11835,2.000000e+03,1.000000e+00,S
4,uL1,,5,V,9.433962e-03,0.000000e+00,0.000000e+00,-10509,11835,4.000000e+05,1.100000e+02,S
5,uL2,,6,V,9.433962e-03,0.000000e+00,0.000000e+00,-10509,11835,4.000000e+05,1.100000e+02,S
6,uL3,,7,V,9.433962e-03,0.000000e+00,0.000000e+00,-10509,11835,4.000000e+05,1.100000e+02,S
7,iEparallel,,64,A,4.608295e-03,0.000000e+00,0.000000e+00,-10509,11835,2.000000e+03,1.000000e+00,S
1,FltRecSta ,,,0
2,M CB RO ,,,0
3,M CB YO ,,,0
4,M CB BO ,,,0
5,T CB RO ,,,0
6,T CB YO ,,,0
.
.
.
3.4,M1/2 CRSND,,,0
35,DT SEND ,,,0
50.0
1
1000.000000,3000
27/04/2023,05:21:51.171000
27/04/2023,05:21:51.671000
BINARY
1.0
Total number of channel 42, analogue channel 7, Digital channel 35
CT ratio 2000,1 type, default value shown in secondary
Description of analogue channel
Description of Digital channel
This is sampling frequency and number of sample. In this case sampling frequency 1000 Hz.
If zero is mention in place of sampling frequency then it means that sampling frequency is variable not fixed
File start time
Fault start time

DATA FILE (REVISED COMTRADE)

ASCII data format
Binary data format

n, timestamp, A_1 ,A_2 , ….., A_k, D_1, D_2, …., D_m<CR/LF>

n:	Sample number
timestamp:	in microsecond = (tstamp x tmult)
A_k:	Analog Sample values
D_k:	Digital Sample values

Sample relative time w.r.t file start time

Sample number

Analogue values

Digital values values

line2.dat - Notepad

File Edit Format View Help

```
  1,        0,  5707,-10649,  4947,     5,   -60,    70,    -8,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  2,      834,  7796,-10181,  2355,   -30,   -69,    60,    11,    3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  3,     1668,  9409, -9028,  -447,   -66,   -71,    44,    29,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  4,     2502, 10388, -7264, -3181,   -56,   -74,    28,    48,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  5,     3336, 10565, -4931, -5656,   -23,   -64,     6,    62,    3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  6,     4170, 10039, -2333, -7795,   -89,   -55,   -13,    71,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  7,     5004,  8874,   462, -9443,  -106,   -41,   -33,    78,    4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  8,     5838,  7107,  3186,-10409,  -117,   -26,   -51,    78,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
  9,     6672,  4803,  5662,-10669,  -203,    -5,   -63,    69,    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 10,     7506,  2183,  7815,-10283,  -285,    13,   -72,    60,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 11,     8340,  -601,  9490, -9104,  -215,    31,   -78,    48,    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 12,     9174, -3310, 10492, -7275,   -93,    48,   -77,    29,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 13,    10008, -5713, 10653, -4938,     1,    59,   -69,     8,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 14,    10842, -7807, 10190, -2357,    27,    68,   -58,   -10,   -1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 15,    11676, -9414,  9031,   436,    54,    72,   -45,   -30,   -3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 16,    12510,-10381,  7261,  3170,    50,    73,   -28,   -48,   -3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 17,    13344,-10562,  4931,  5647,    15,    65,    -5,   -62,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 18,    14178,-10038,  2330,  7787,    79,    54,    14,   -72,   -4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 19,    15012, -8869,  -461,  9441,   111,    43,    34,   -77,    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 20,    15846, -7104, -3186, 10418,   128,    26,    51,   -79,   -3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 21,    16680, -4797, -5671, 10659,   190,     5,    64,   -70,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 22,    17514, -2181, -7816, 10287,   291,   -13,    72,   -61,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 23,    18348,   599, -9491,  9117,   225,   -32,    78,   -47,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 24,    19182,  3307,-10492,  7284,    99,   -49,    78,   -29,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 25,    20016,  5706,-10646,  4949,     9,   -59,    70,    -7,    4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 26,    20850,  7798,-10185,  2354,   -33,   -67,    58,    11,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 27,    21684,  9414, -9027,  -449,   -62,   -71,    46,    30,    4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 28,    22518, 10386, -7261, -3181,   -55,   -72,    27,    49,    4,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 29,    23352, 10567, -4935, -5657,   -25,   -64,     4,    62,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 30,    24186, 10042, -2331, -7795,   -84,   -56,   -13,    70,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 31,    25020,  8872,   464, -9452,  -116,   -43,   -33,    78,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 32,    25854,  7112,  3182,-10415,  -122,   -25,   -50,    78,    3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 33,    26688,  4803,  5662,-10664,  -199,    -5,   -64,    71,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 34,    27522,  2183,  7815,-10284,  -287,    14,   -72,    61,    2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 35,    28356,  -598,  9490, -9098,  -205,    31,   -77,    46,    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 36,    29190, -3312, 10494, -7277,   -94,    48,   -77,    30,    1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 37,    30024, -5716, 10651, -4939,    -5,    60,   -70,     9,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 38,    30858, -7802, 10192, -2364,    26,    67,   -60,   -11,   -3,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 39,    31692, -9415,  9033,   432,    50,    73,   -46,   -29,   -1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 40,    32526,-10379,  7256,  3165,    42,    73,   -27,   -48,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
 41,    33360,-10560,  4932,  5643,    14,    65,    -5,   -61,   -2,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
```

How .cfg and .dat connect with each other?

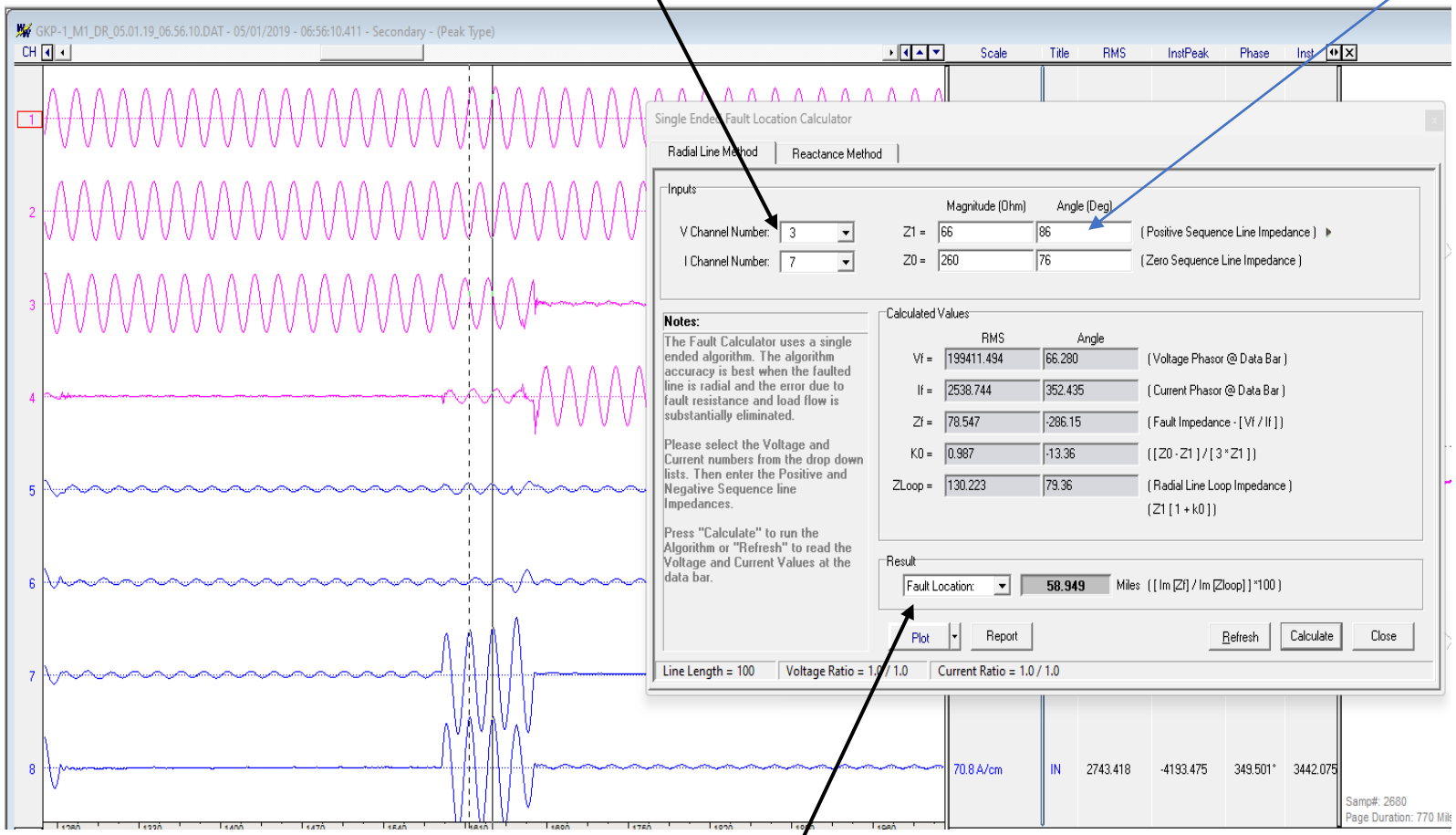
Their name must be same

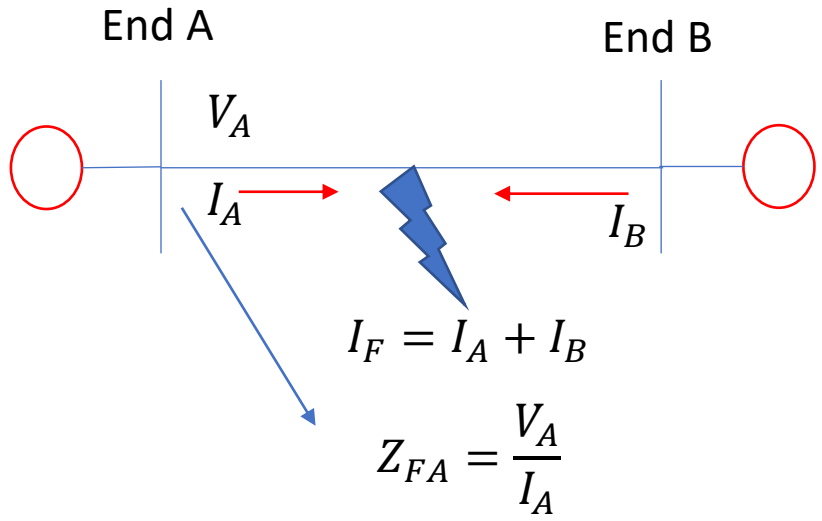
Fault Calculation

Data>fault calculator>single ended

Select the channel where fault is there manual selection

Positive and zero sequence impedance





Voltage drop due to I_B is not seen by A end relay. That's why Double ended calculation is required.

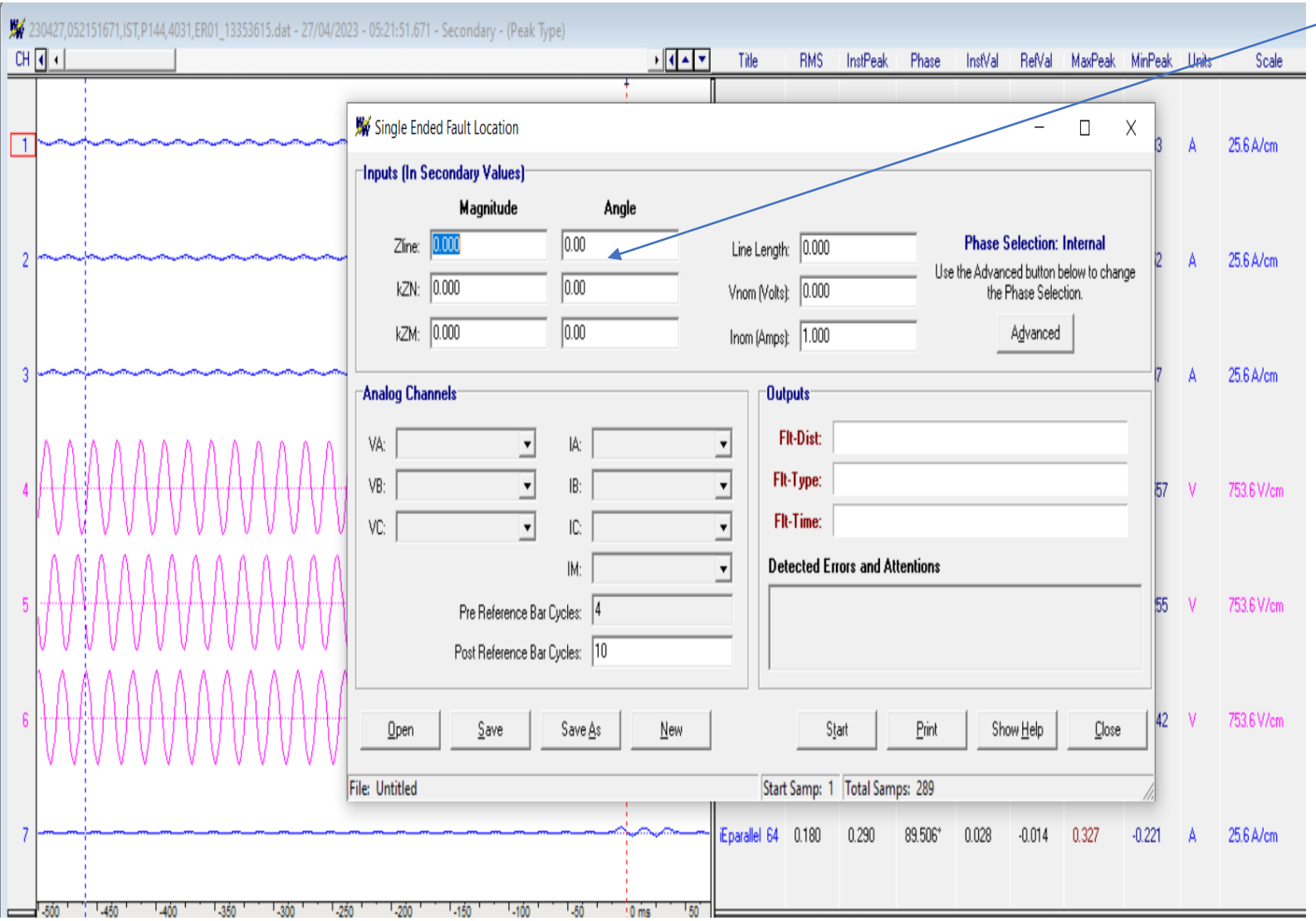
Accuracy will be better with double ended method but needs time sync other end DR for that.

Output: % fault distance or Fault impedance

Fault Calculation

Data>fault Detector

Positive and zero sequence impedance

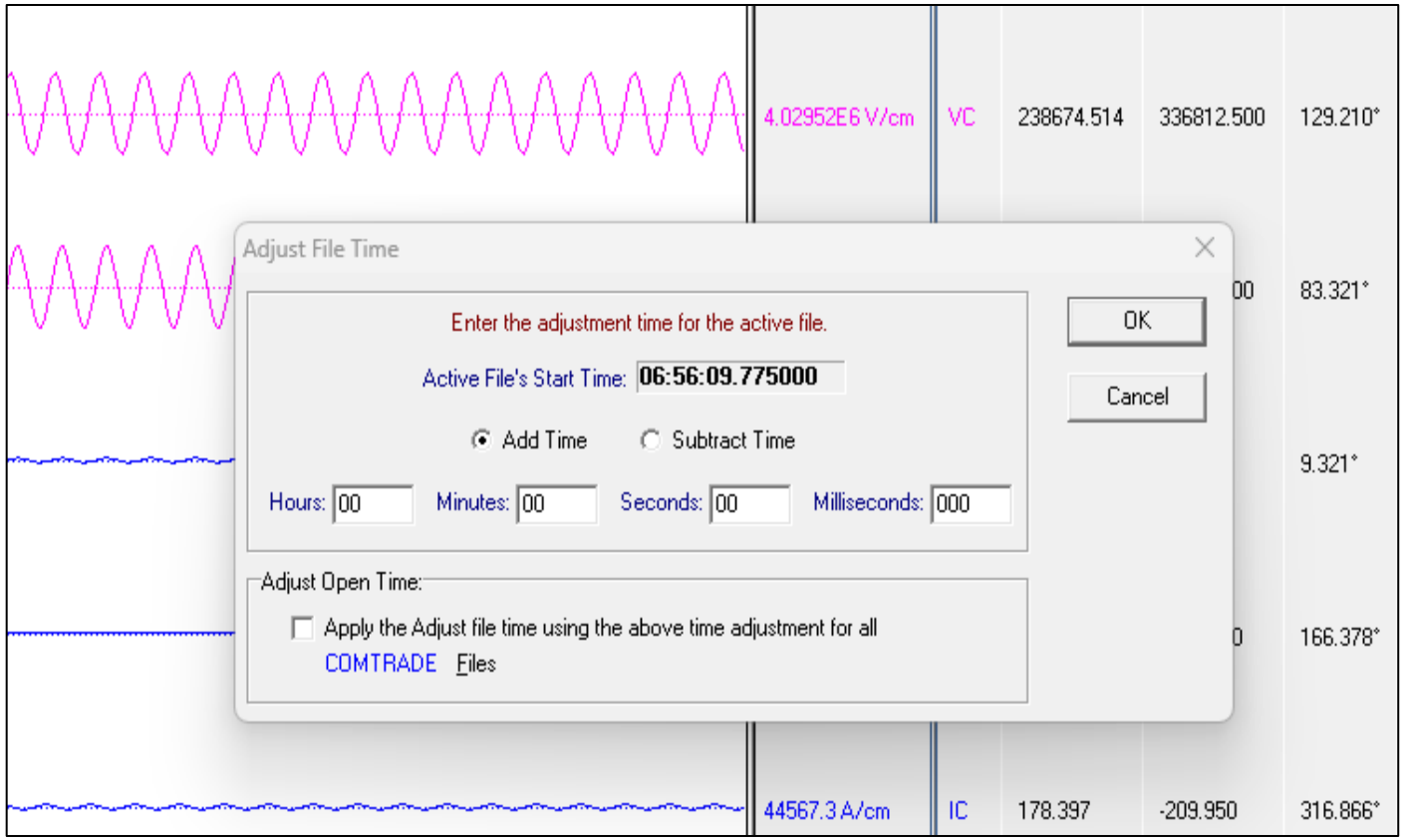


- In this method automatically fault time is detected. No need to select the data by moving the pointer

- Fault distance detected
- Faulted Phase detected

Time Adjustment

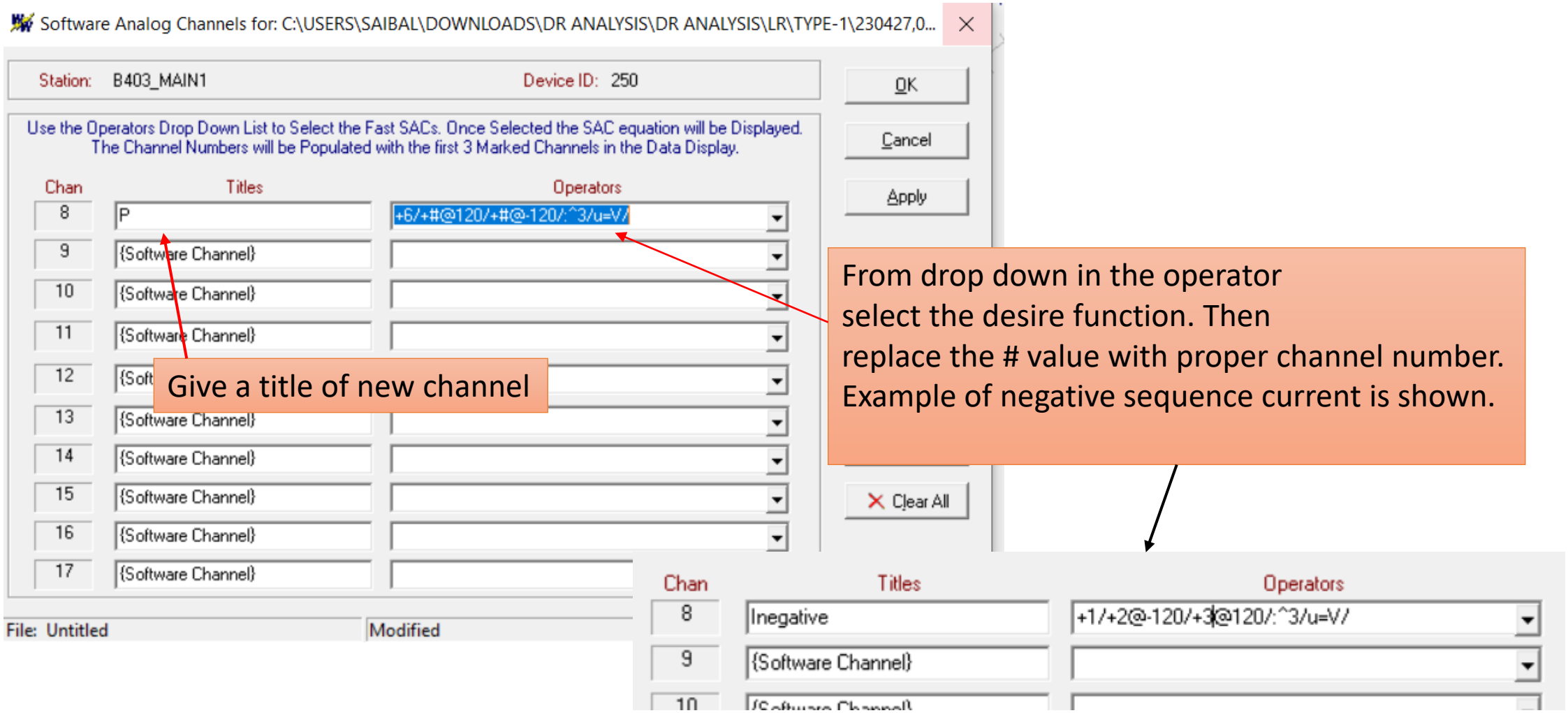
Data>Adjust file times



- During a disturbance involving multiple location we need to sync the DR time. From PMU we
  can decide the start time, then for each file we may add or minus required time to bring all of them in same time frame

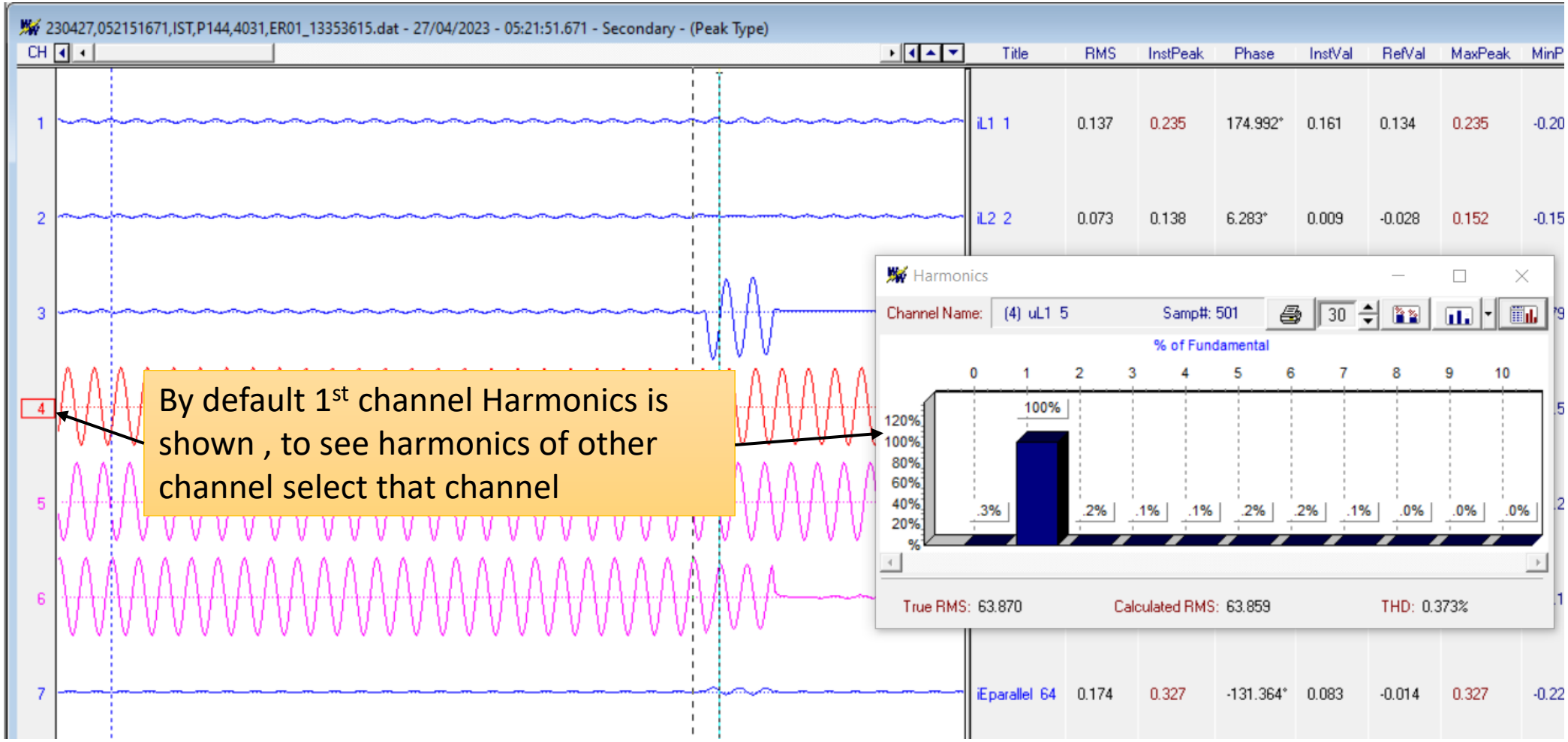
- For international line with different time zone also we can do this adjustment. So that we can analyse them together.

Channel >Software analogue channel



Finally click apply and Ok , in the DR window now a new channel will be added

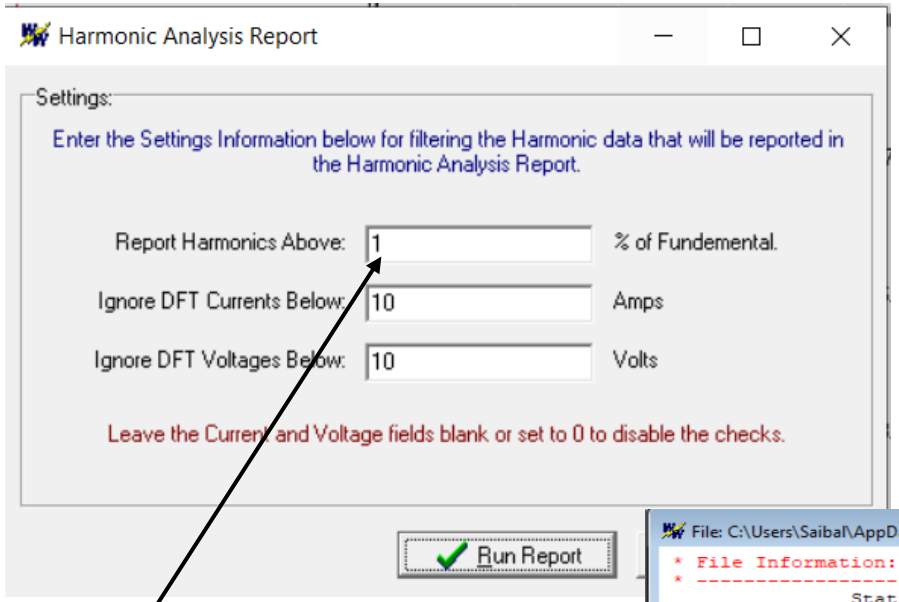
Harmonics



View >Harmonics Table

Data>Harmonics Analysis report

The difference between Harmonics table and this report is that in previous method the analysis is done for a particular time where the pointer is there.
In this method complete analysis of the total time window is done for all the channel



Minimum % of Fundamental which needs to be reported

Start of Harmonics

Duration of harmonics

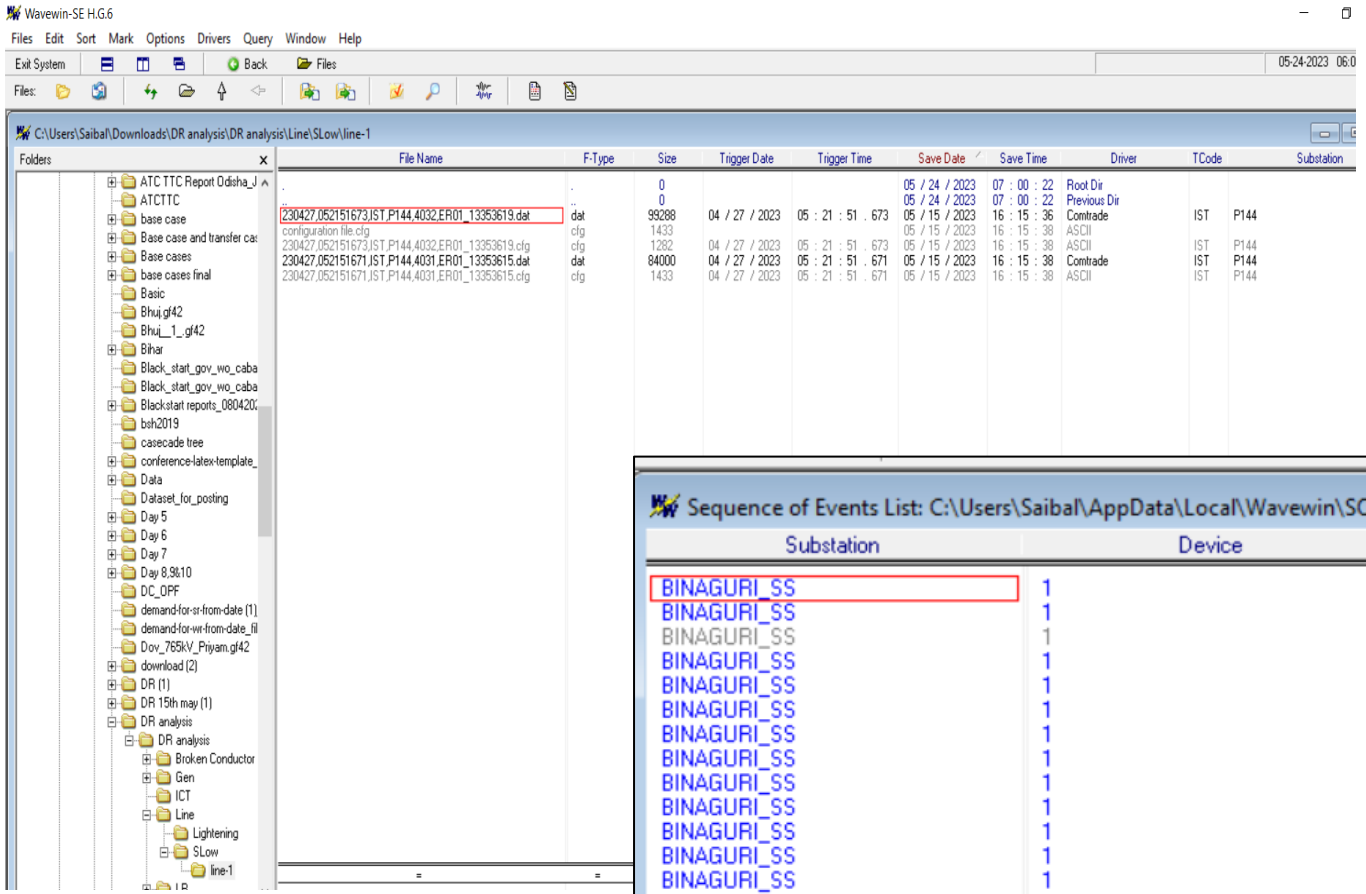
File: C:\Users\Saibal\AppData\Local\Wavewin\upgrades-list.txt

```
* File Information::
* ------------------
                Station: B403 MAIN1
                 Device: 4031
              File Name: C:\USERS\SAIBAL\DOWNLOADS\DR ANALYSIS\DR ANALYSIS\LR\TYPE-1\230427,052151671,IST,P144,4031,ER01 13353615.dat
              File Size: 84000 Bytes
          Prefault Time: 27/04/2023 05:21:51.171000
           Trigger Time: 27/04/2023 05:21:51.671000
              Save Time: 05-15-2023 16:15:38
     Start Date && Time: 27/04/2023 05:21:51.171000
       End Date && Time: 27/04/2023 05:21:54.170000
          File Duration: 2  Sec(s) - 999 Mils(s)
     Sampling Frequency: 1000.000000, 1000.000 Microsecond Rate
         Line Frequency: 50.000000
   Show Harmonics Above: 1% of Fundemental
  Ignore Currents Below: 10.000 Amps
  Ignore Voltages Below: 10.000 Volts

* Harmonic Analysis Report
* -------------------------
#  Channel (4) uL1  5 V
>    Harm.    Date & Time                  Sample #    Magnitude       Fundemental     % of Fund.      Duration
     01       27/04/2023 05:21:53.846000   2676        90.390          90.390          100.000         2981
#  Channel (5) uL2  6 V
>    Harm.    Date & Time                  Sample #    Magnitude       Fundemental     % of Fund.      Duration
     01       27/04/2023 05:21:52.341000   1171        90.961          90.961          100.000         2981
#  Channel (6) uL3  7 V
>    Harm.    Date & Time                  Sample #    Magnitude       Fundemental     % of Fund.      Duration
     00       27/04/2023 05:21:52.799000   1629        47.878          85.148          56.229          135
     01       27/04/2023 05:21:52.808000   1638        97.602          97.602          100.000         2662
     02       27/04/2023 05:21:52.793000   1623        39.419          50.839          77.537          32
     03       27/04/2023 05:21:52.795000   1625        22.023          72.418          30.411          24
     04       27/04/2023 05:21:52.792000   1622        14.403          38.832          37.092          9
     05       27/04/2023 05:21:52.794000   1624        12.100          62.529          19.350          2
```

Generate SOE from Digital Channel

Open wavewin.exe and then open the desired folder where DRs are there. Window will look like below:



Step-2: select the .dat file and in the top menu bar :
Option>report>SOE list

This will give a SOE list based on the digital signal and make analysis easy

Sequence of Events List: C:\Users\Saibal\AppData\Local\Wavewin\SOE LIST.CSV

Substation	Device	State	Trigger Date	Trigger Time	Ch...	Channel Title
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 28 . 899096	27	MAIN-1_Z3_START
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 28 . 947410	26	MAIN-1_Z2_START
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 152328	26	MAIN-1_Z2_START
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 168988	26	MAIN-1_Z2_START
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 378904	16	R23 3PH GRP-B OP
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 378904	15	R22 3PH GRP-A OP
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 378904	7	MAIN-1-TRIP
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 378904	4	MAIN-1_Z2_OPTD
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 407226	11	MCB_AR_LOCKOUT
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 418888	36	L14 TCB_YPH_OPEN
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 418888	35	L13 TCB_RPH_OPEN
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 417222	37	L15 TCB_BPH_OPEN
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 417222	3	L3 MCB_BPH_OPEN
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 417222	2	L2 MCB_YPH_OPEN
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 417222	1	L1 MCB_RPH_OPEN
BINAGURI_SS	1	A	21 / 04 / 2023	21 : 29 : 29 . 423886	8	L10 M2_PROTN_OPT
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 433882	27	MAIN-1_Z3_START
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 433882	26	MAIN-1_Z2_START
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 433882	16	R23 3PH GRP-B OP
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 433882	15	R22 3PH GRP-A OP
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 433882	4	MAIN-1_Z2_OPTD
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 437214	8	L10 M2_PROTN_OPT
BINAGURI_SS	1	N	21 / 04 / 2023	21 : 29 : 29 . 458872	7	MAIN-1-TRIP

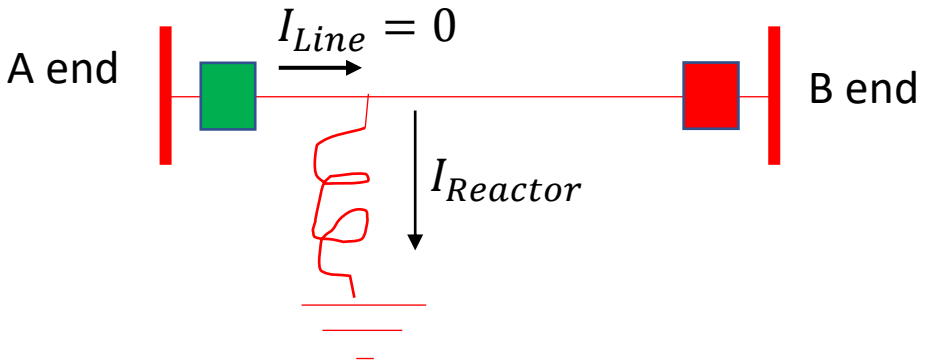
Anti theft/Idle charged line/AR successful from one end only

Type-1: In such cases line without any LR will remain charged from one end and charging current will flow. So Angle between the voltage and current will be 90 degree.

Type-2: However there are few special consideration for lines where L/R is there. These are as follows:

1. Case 1: Current used in distance protection = Line current – LR current
2. Case 2: Current used in distance protection = Line current

These two case are very tricky and proper analysis is required.

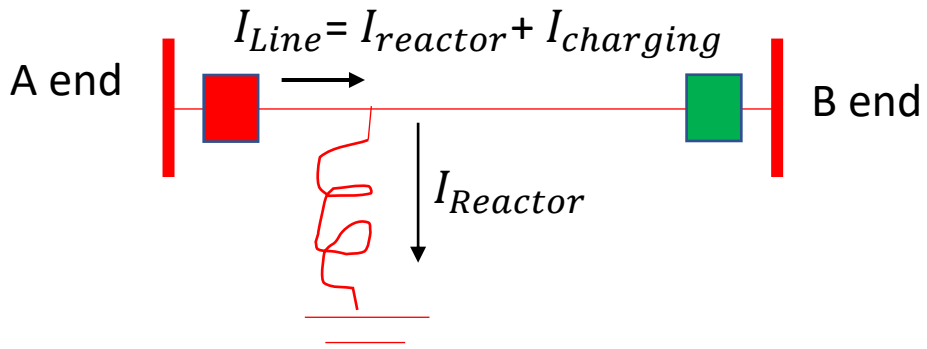


Case -1

$$I_{relay} = I_{Line} - I_{reactor} = -I_{reactor}$$

Case -2

$$I_{relay} = I_{Line} = 0$$



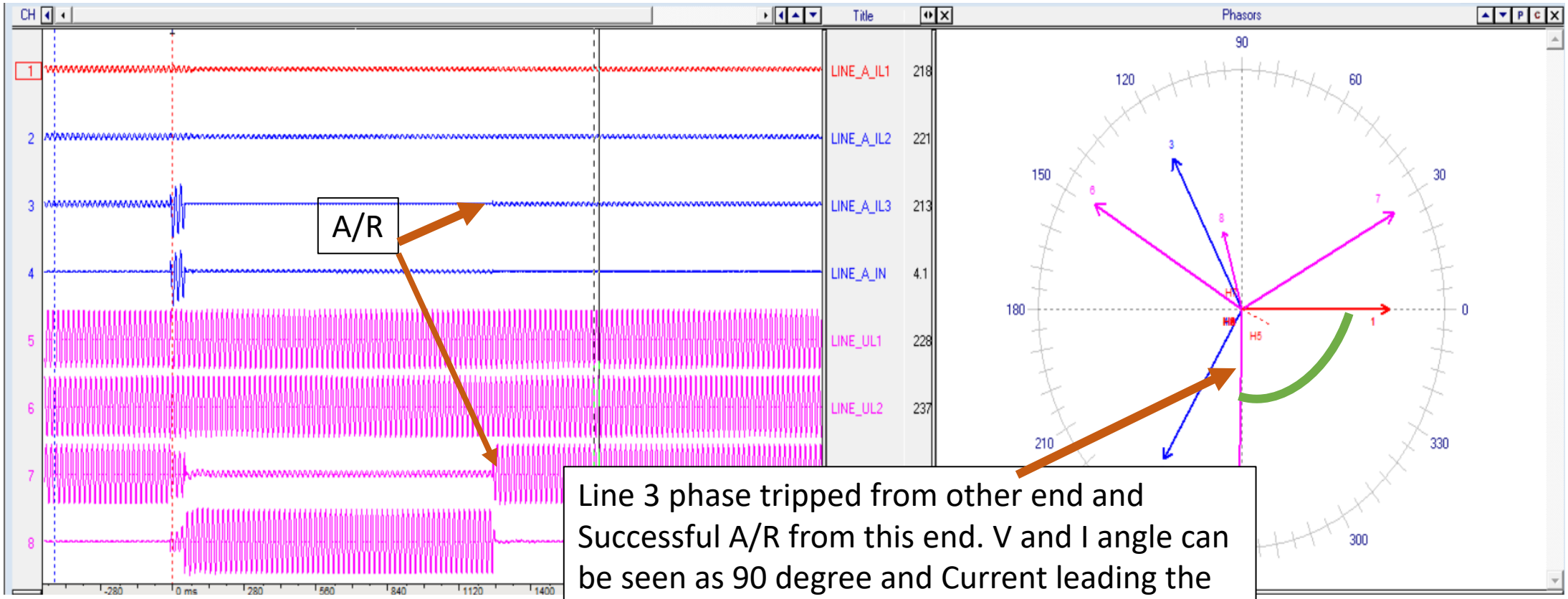
Case -1

$$I_{relay} = I_{Line} - I_{reactor} = I_{reactor} + I_{charging} - I_{reactor} = I_{charging}$$

Case -2

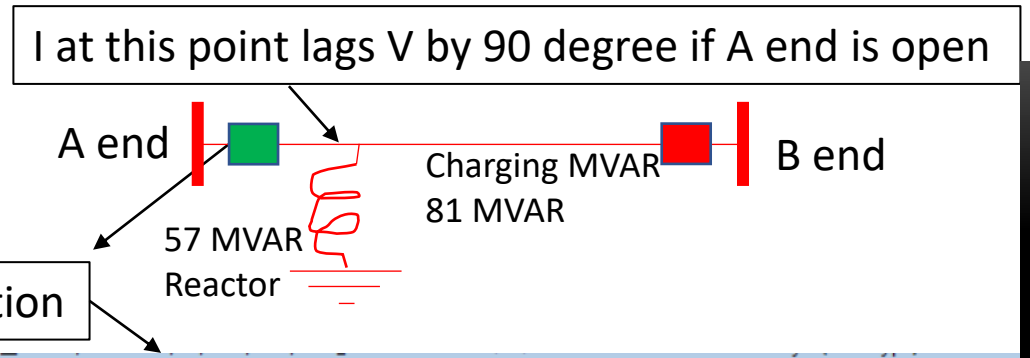
$$I_{relay} = I_{Line} = I_{charging} + I_{reactor}$$

Type 1: Line has no L/R and AR successful from One end and immediate three phase tripping from other end:

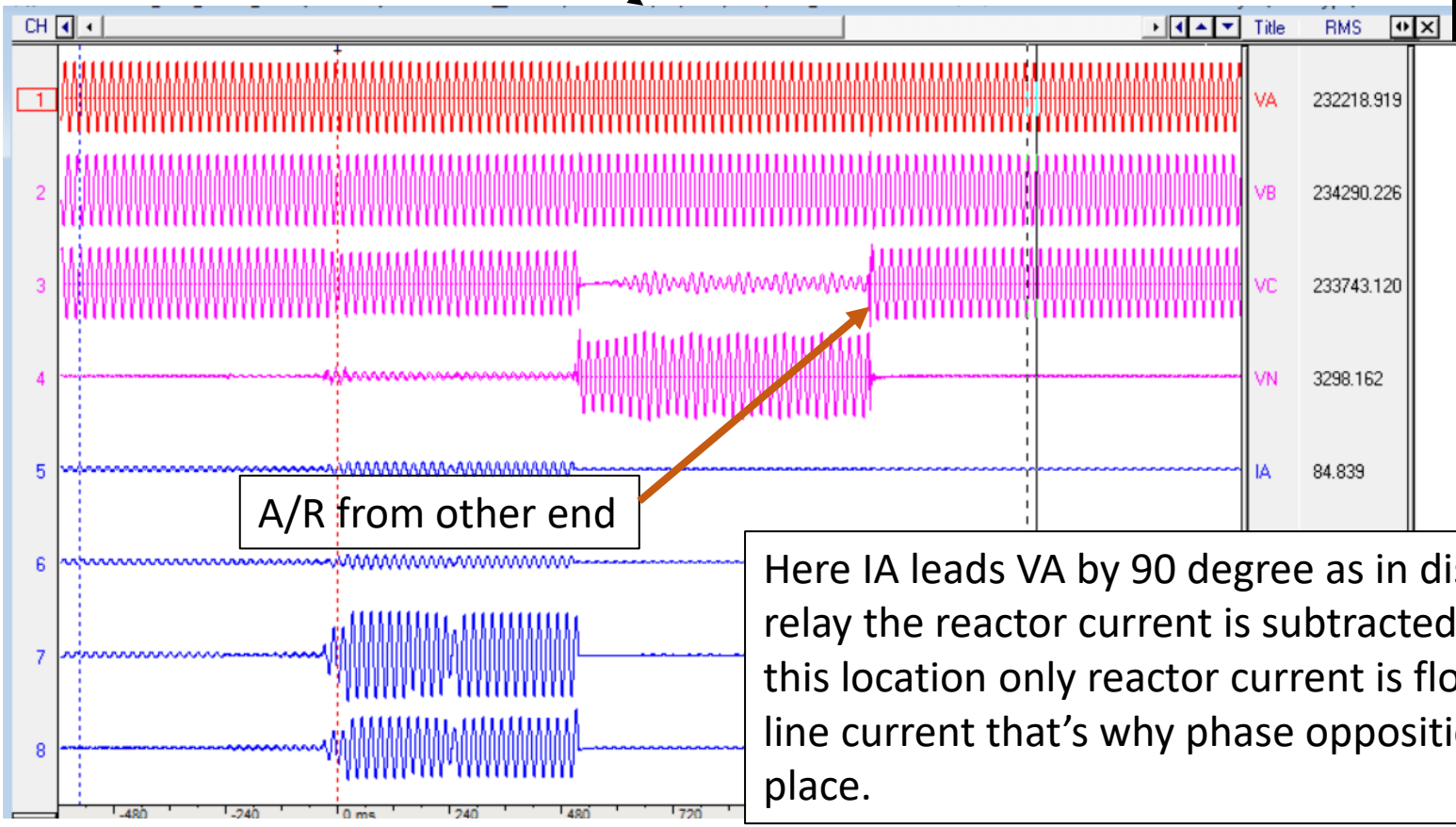


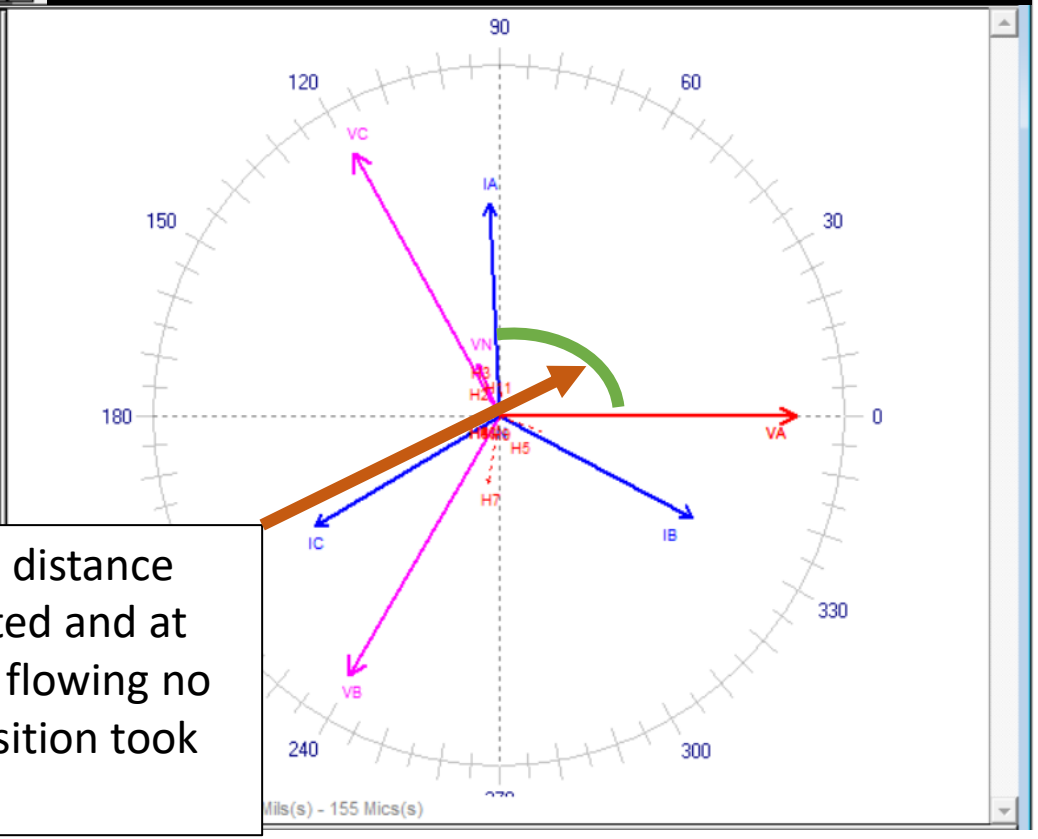
Line 3 phase tripped from other end and Successful A/R from this end. V and I angle can be seen as 90 degree and Current leading the voltage. This is true for all the phases after A/R. Before A/R only the live two phase V and I angle were 90 degree.

Case-1: Line has L/R and AR successful from only One end and LR current is **subtracted** from Line current in Distance protection:



Also it is important to check value of current:
1. If line charged from A end then current =only charring current i.e 81 MVAR
2. If line charged from B end then current= reactor current i.e 57 MVAR

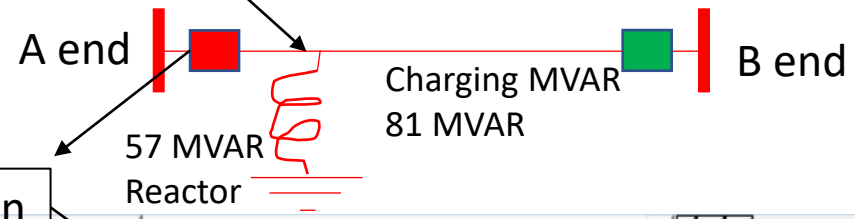




Here IA leads VA by 90 degree as in distance relay the reactor current is subtracted and at this location only reactor current is flowing no line current that's why phase opposition took place.

Case-2: Line has L/R and AR successful from only One end and LR current is **not subtracted** from Line current in Distance protection:

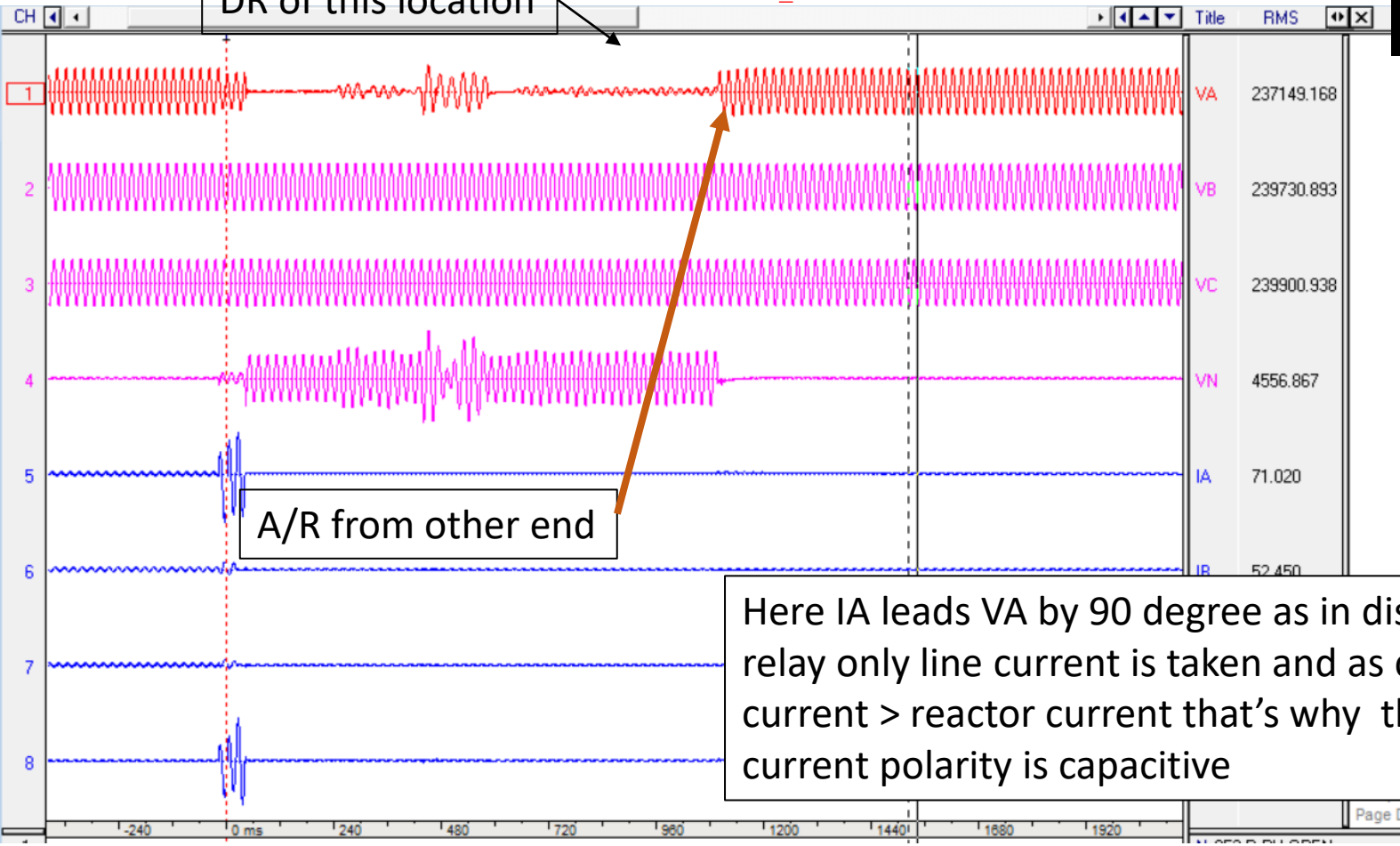
I at this point leads V by 90 degree as $MVAR_{reactor} < MVAR_{charging}$

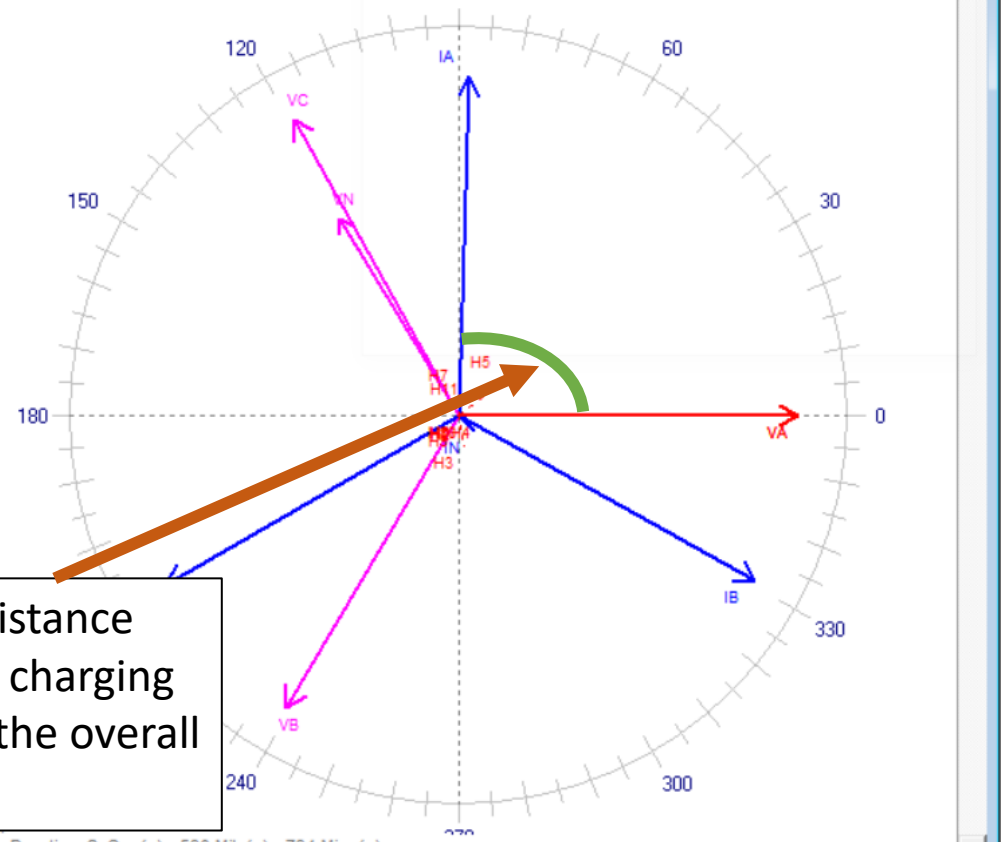


Also it is important to check value of current:

1. If line charged from A end then current =Charging + Reactor current
2. If line charged from B end then current= 0

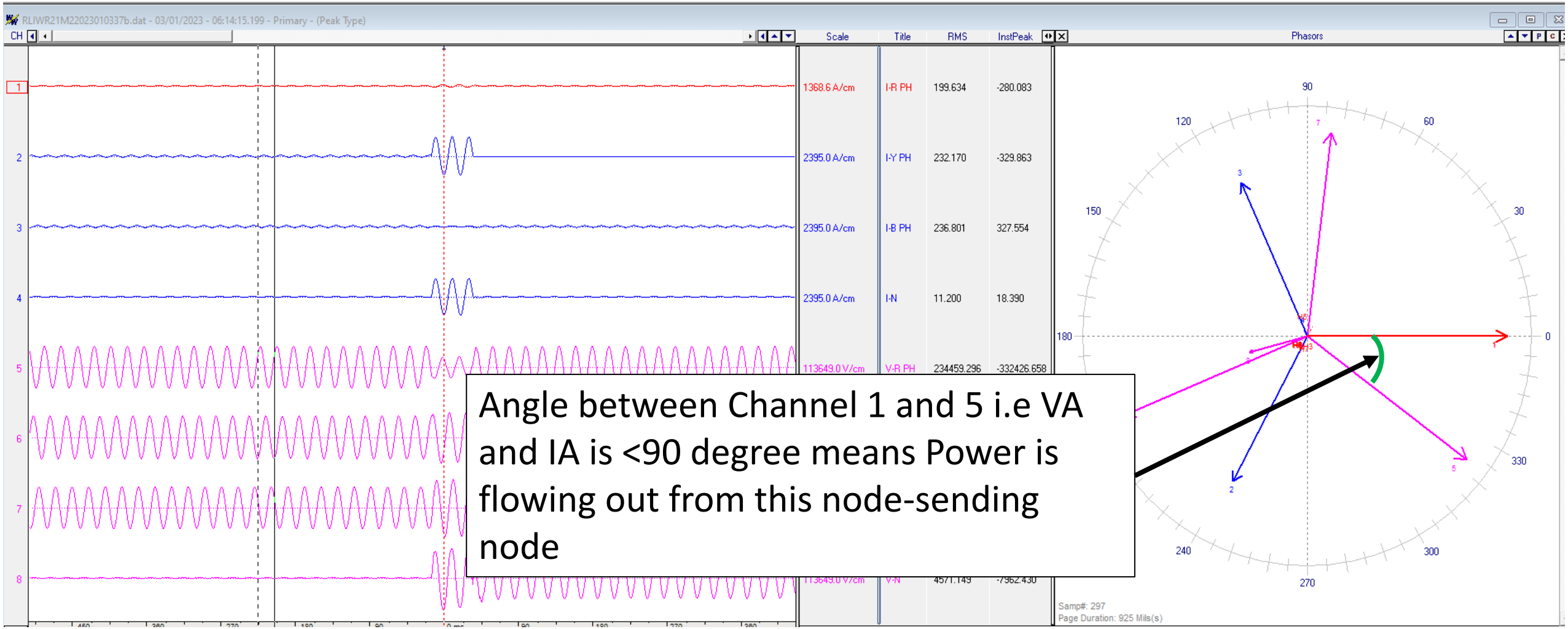
DR of this location





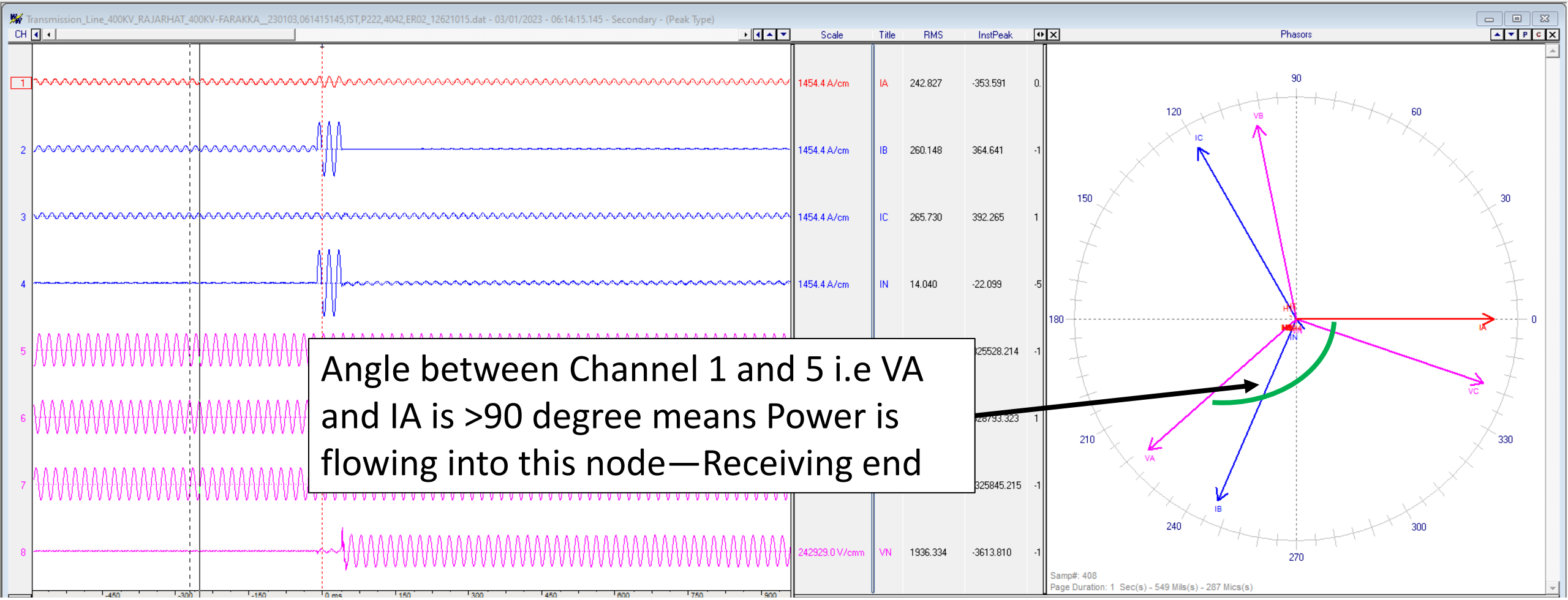
Here IA leads VA by 90 degree as in distance relay only line current is taken and as charging current > reactor current that's why the overall current polarity is capacitive

Identify Sending and Receiving end



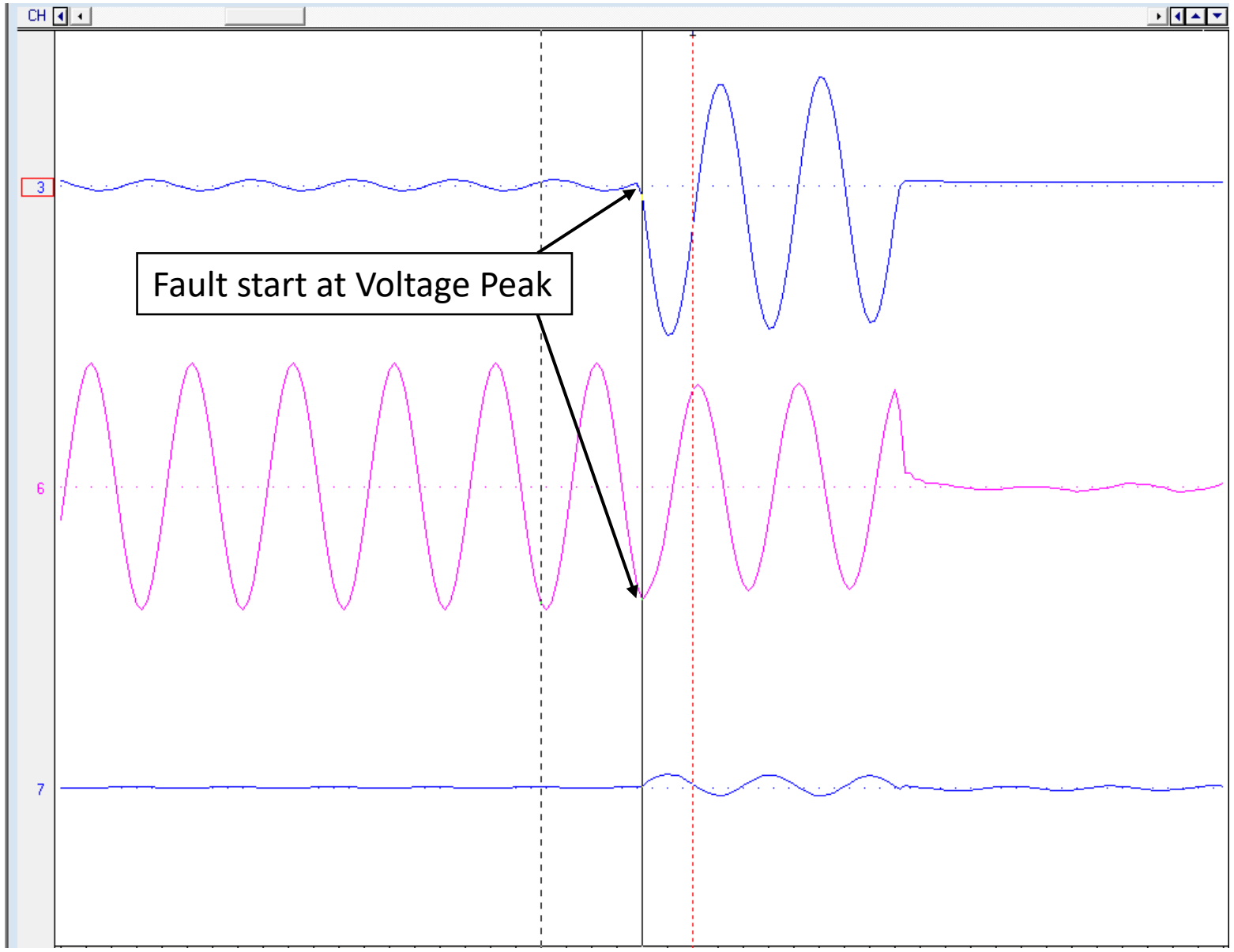
Angle between Channel 1 and 5 i.e VA and IA is <90 degree means Power is flowing out from this node-sending node

Identify Sending and Receiving end



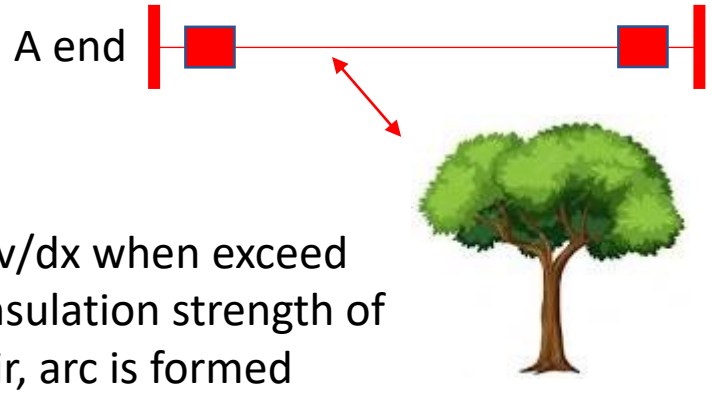
Angle between Channel 1 and 5 i.e VA and IA is >90 degree means Power is flowing into this node—Receiving end

Slow Fault Building Mechanism



- During Slow fault building mechanism Like vegetation fault, conductor snapping etc Fault take place at the voltage peak.

  dV/dt very fast as compared to dx/dt

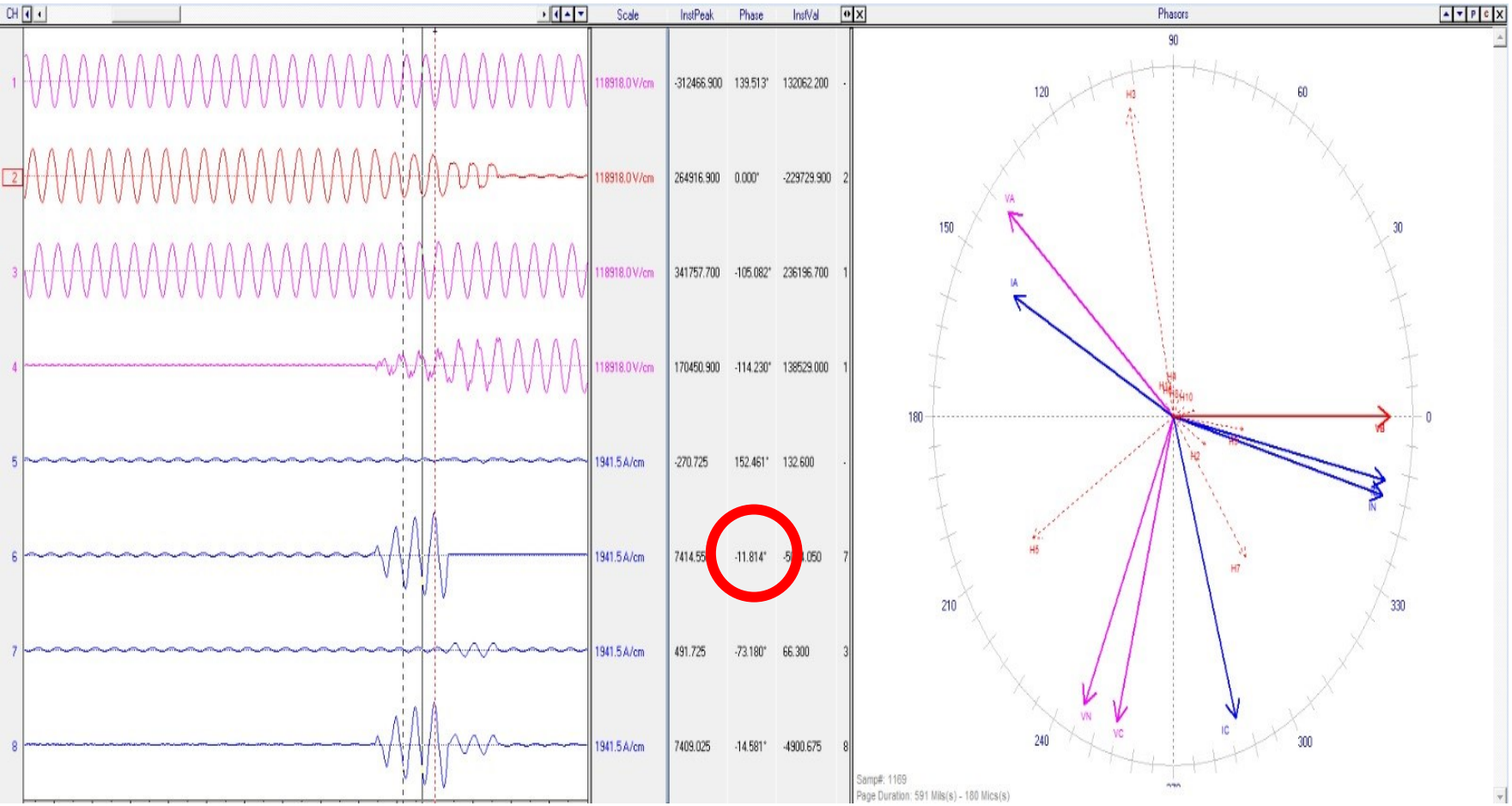


dv/dx when exceed insulation strength of air, arc is formed

In Vegetation fault higher resistance is involved
so V & I angle is lesser compared to line angle

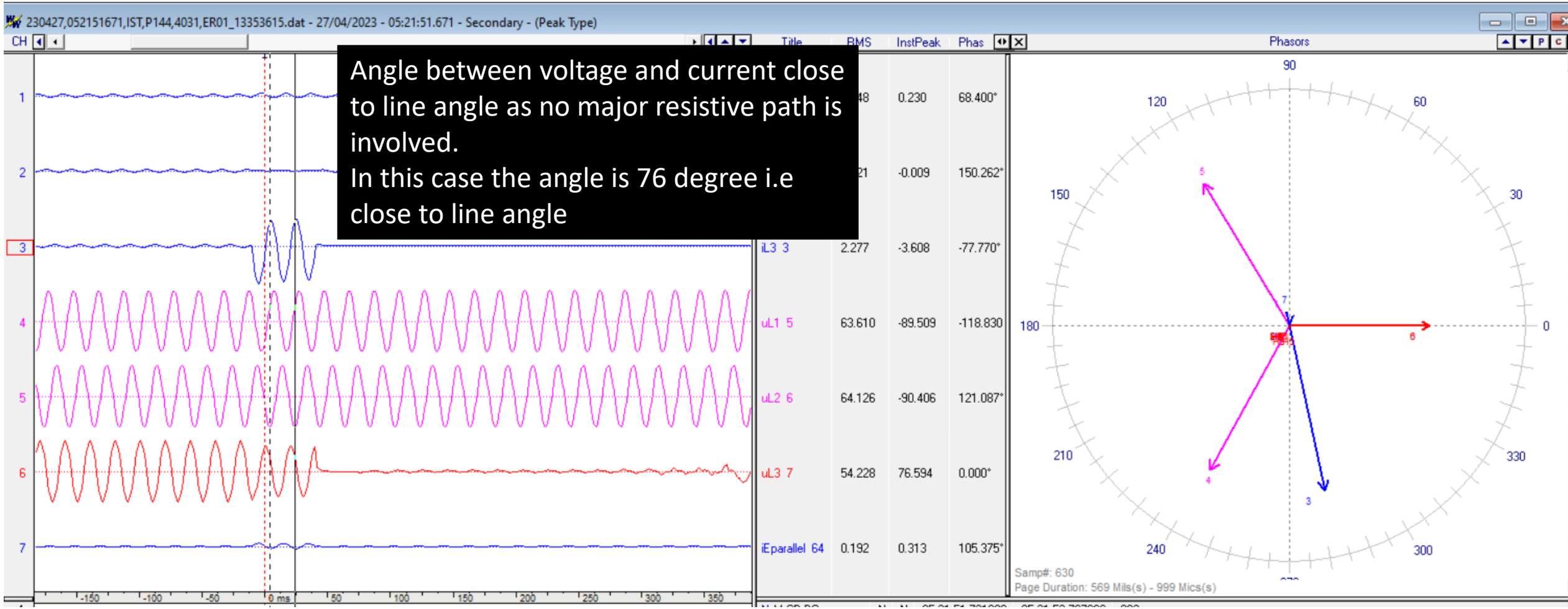
Vegetation fault

Line Angle= $\tan^{-1}\frac{X_{line}}{R_{line}}$

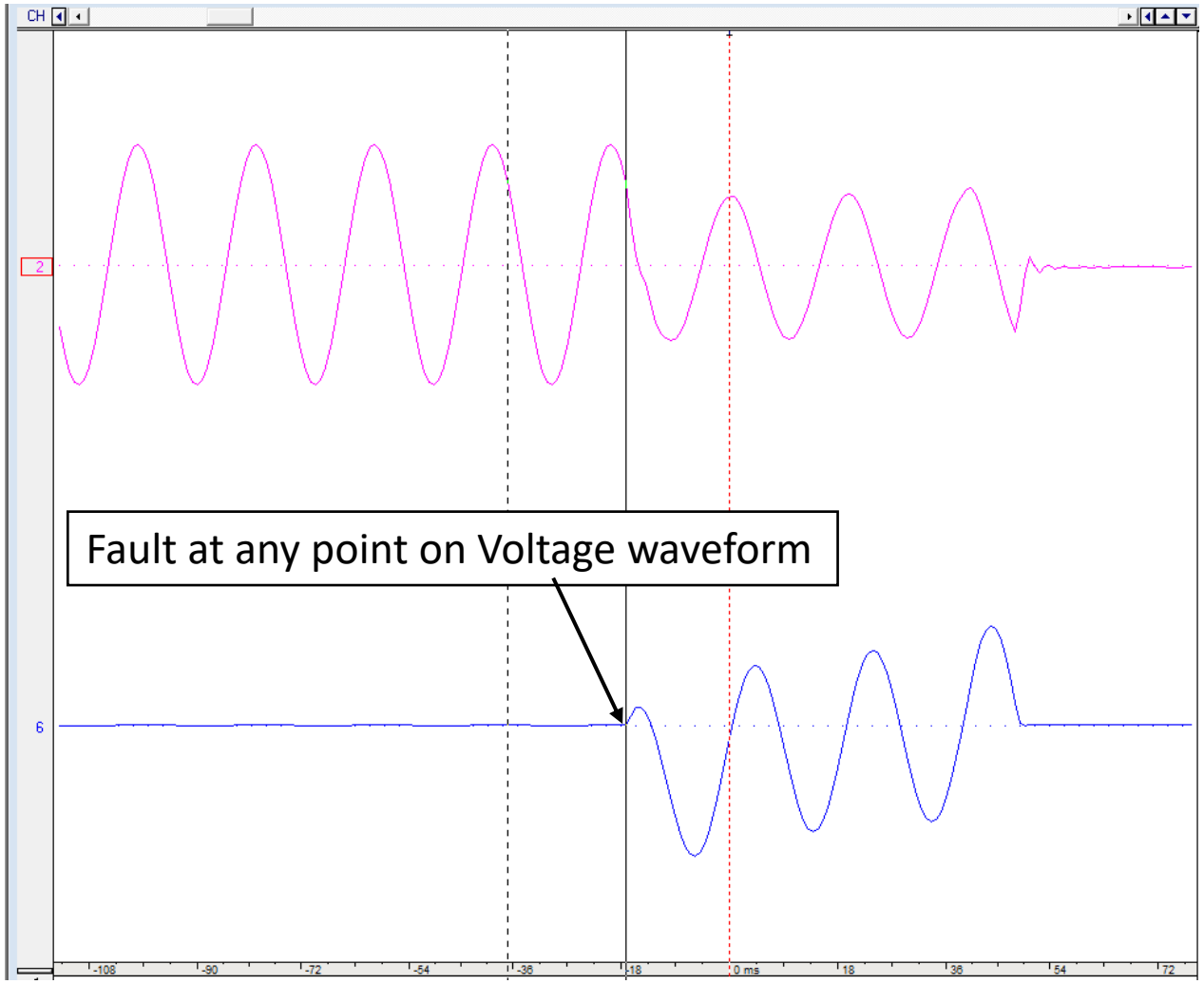


- Angle between Voltage and Current much less than the line angle. In a 400 kV line angle is around 80 to 84 degree,
- However it the above fault it is seen that the angle between V and I is only 11 degree. Indicating High resistance in the fault loop.
- This could be due to Vegetation fault

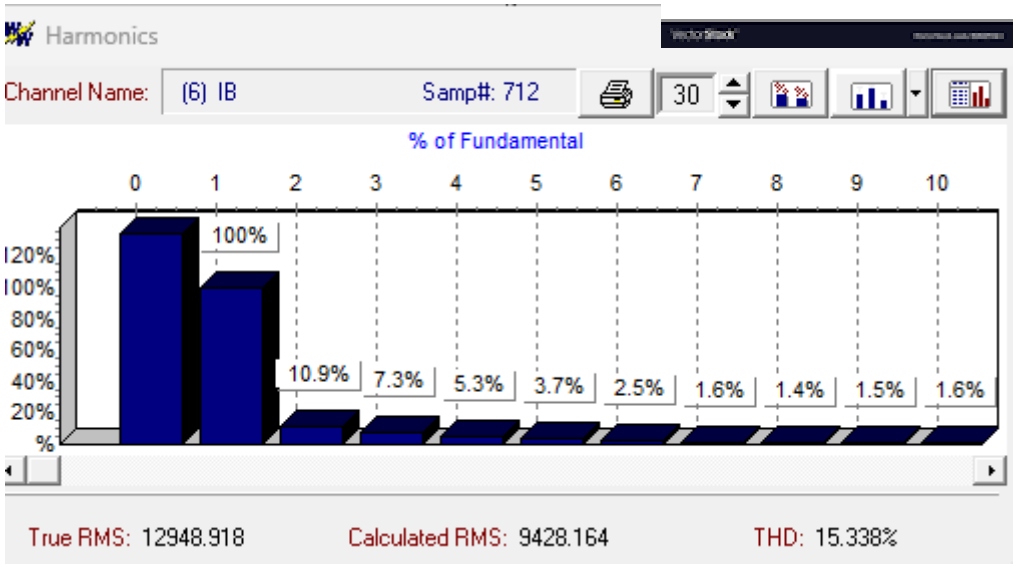
Another type of slow fault building mechanism is some solid fault due to kite thread, jumper snaping ect.
In this type resistance of the fault loop is less



Lightening Fault

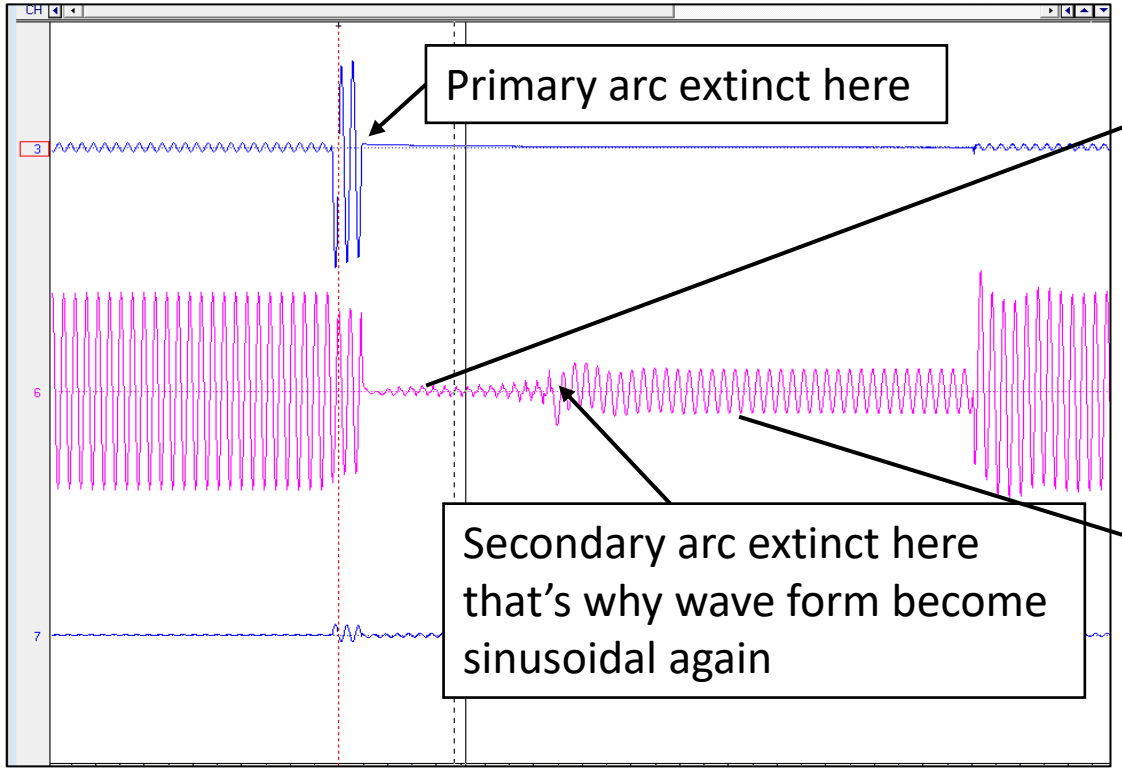


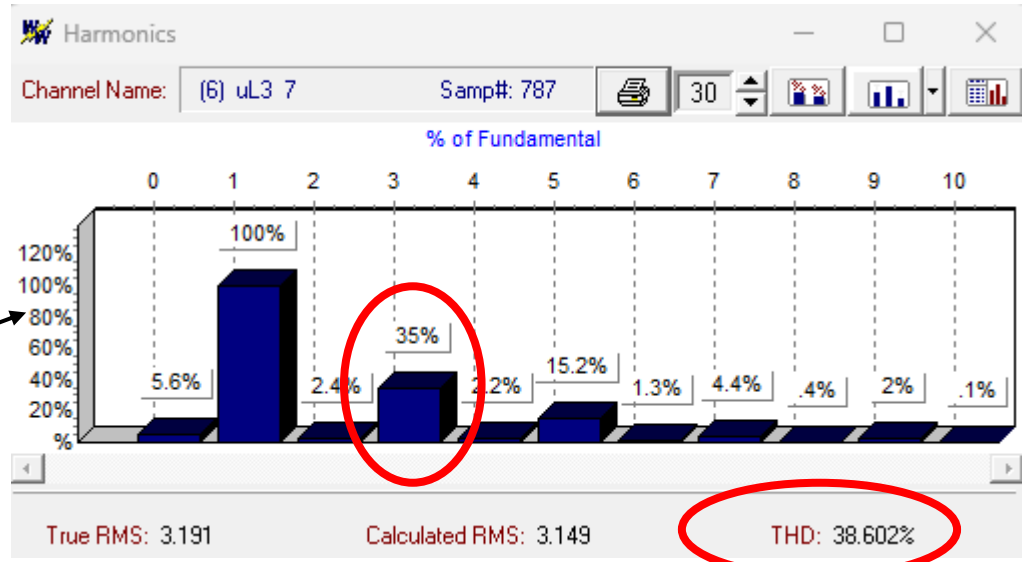
In lightening fault, generally back flashover between tower and live phase wire took place. No resistive path is involved hence Fault Angle is close to Line angle.

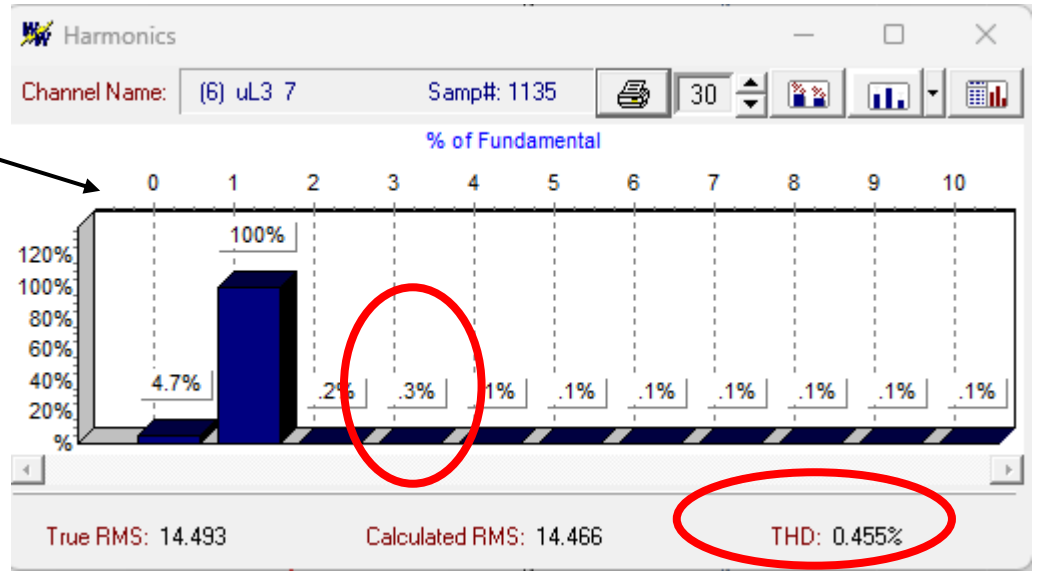


High DC component, Fault can occur at any point in the voltage wave form

Secondary Arc Phenomena

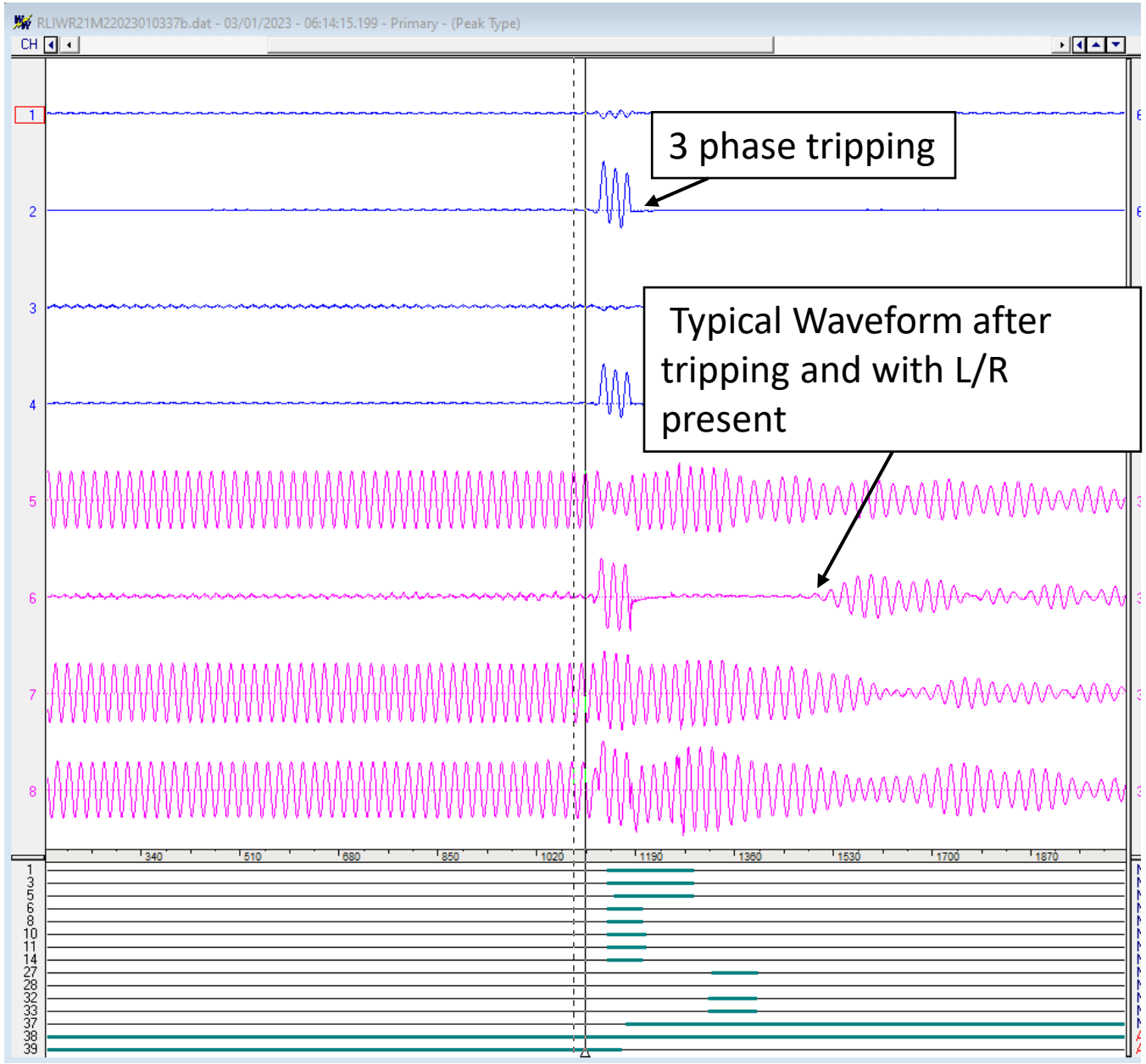






Distorted waveform , High Harmonics content during Secondary arc period

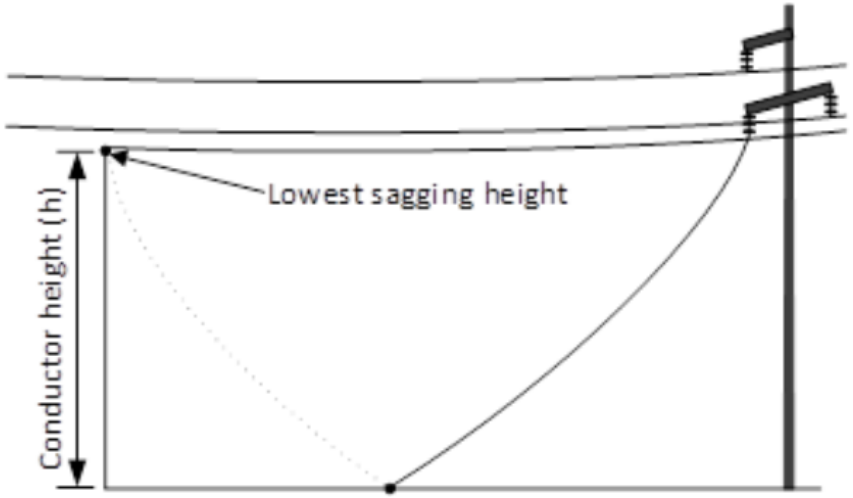
Signature of Line after Tripping Where L/R is present



Lines which are shunt compensated have typical voltage waveform like this even after three phase tripping from both end.

The frequency of these waveform depends on the percentage of compensation.

Broken Conductor



When a conductor snapping happens, it takes almost 0.6 sec to 1 sec for touching other phase or ground and develop fault.

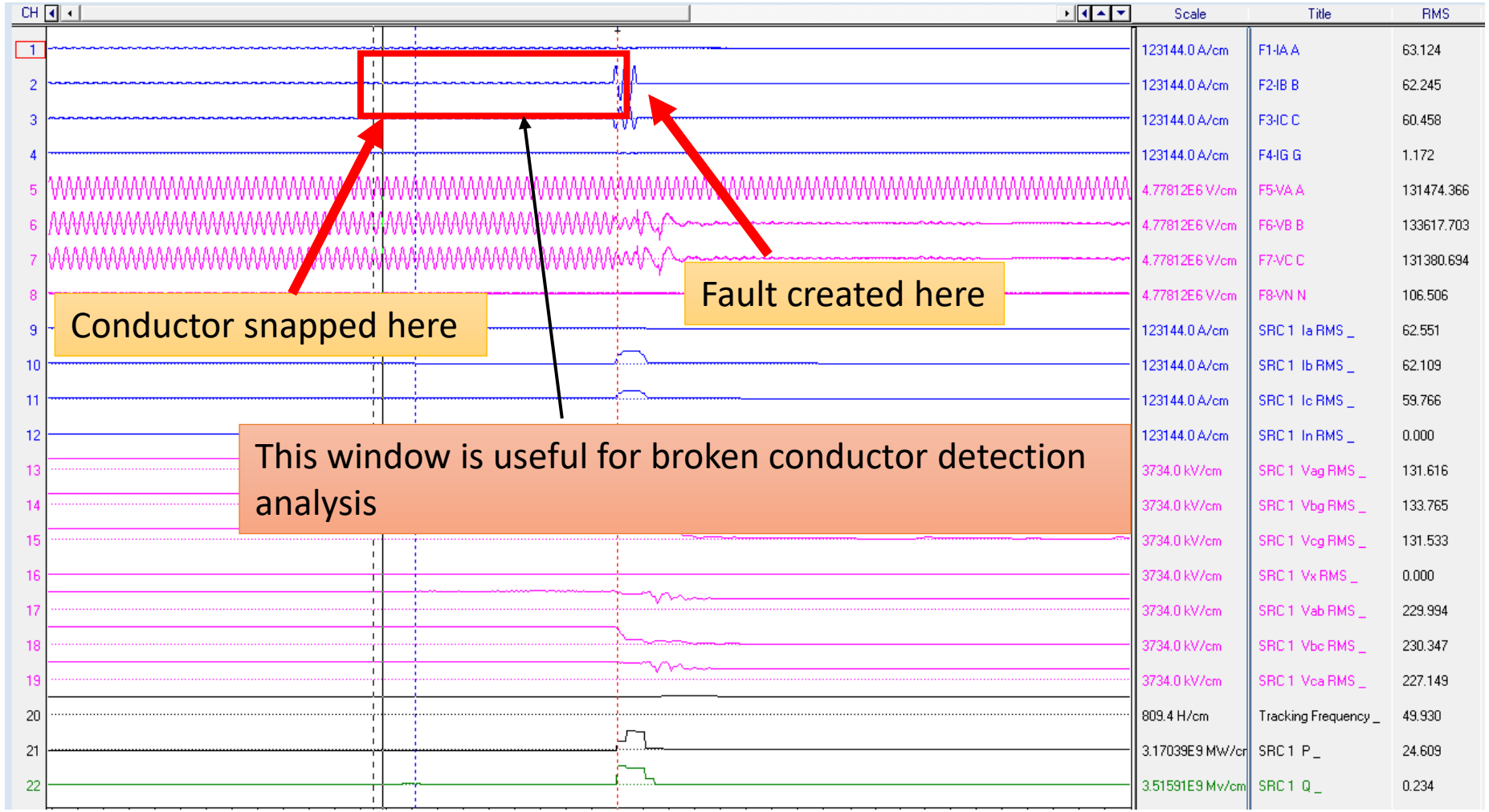
$$h = \frac{1}{2}(g.t^2) \rightarrow t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2x5.6}{9.8}} = 1.06s$$

Using this signature it can reliably decided conductor snapping event by system operator and line charging decision can be taken

Detection method

1. I2 / I1 broken-conductor detection method
2. V0 and V2 angle
3. V0 and V2 magnitude
4. Impedance based detection

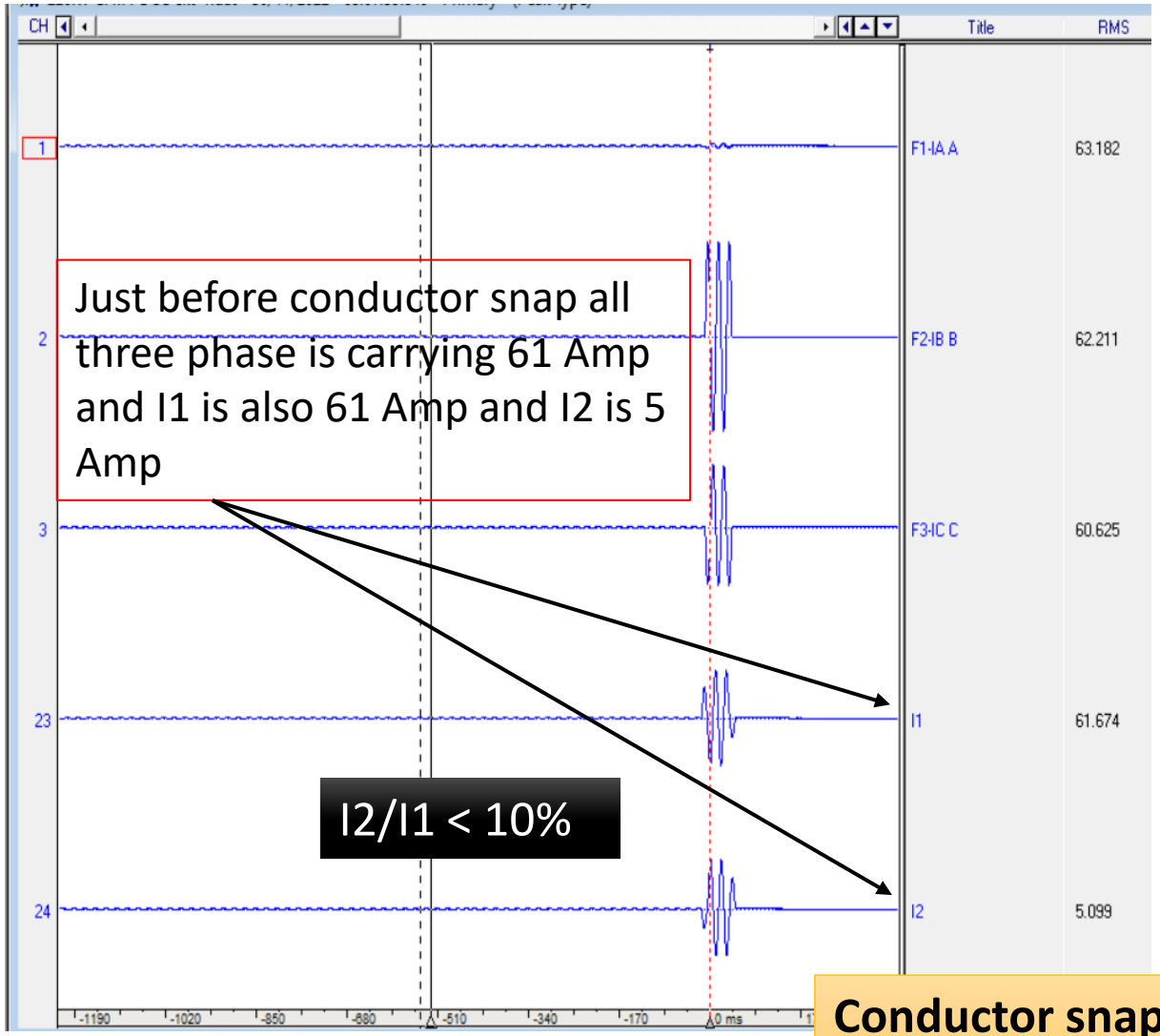
Case study: Tripping of 220 kV line on 30-11-2022 at 05:07 hrs

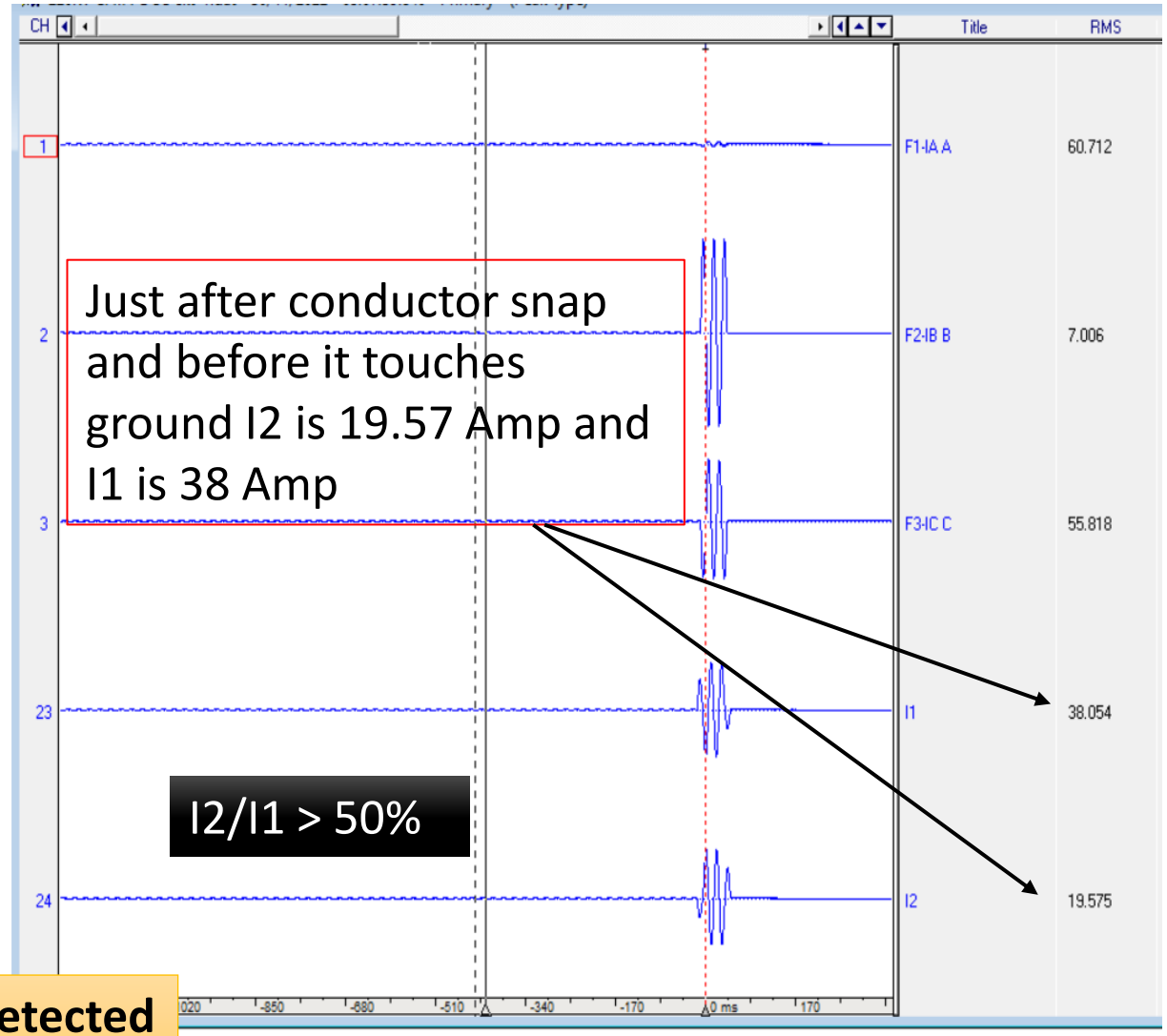


On 30th Nov 2022 220 kV line tripped due to Y-B phase fault as Y phase conductor snapped on B phase.

Case study: Tripping of 220 kV line on 30-11-2022 at 05:07 hrs

- I2 / I1 broken-conductor detection method- Gaya end DR:

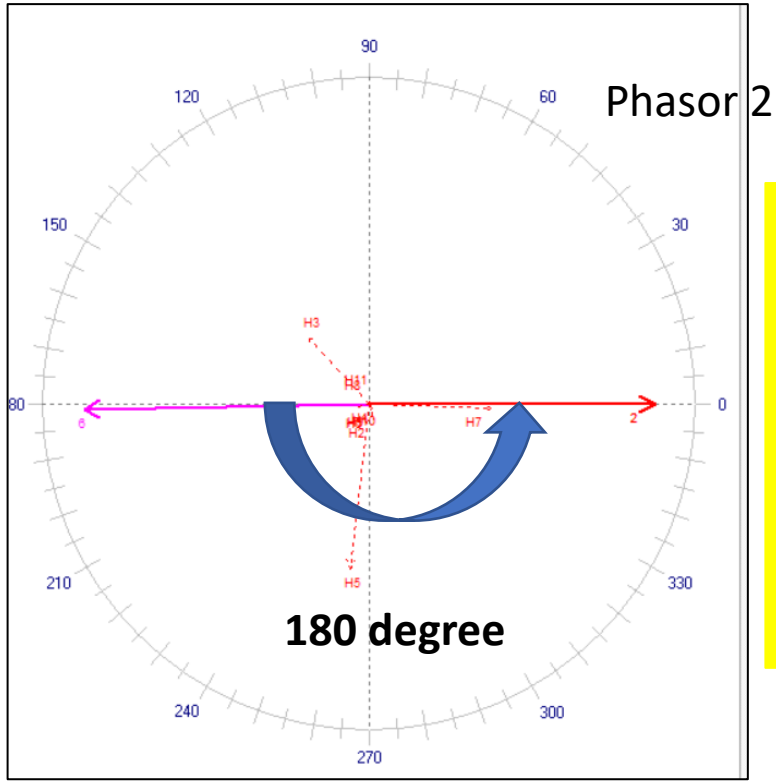




Conductor snap detected

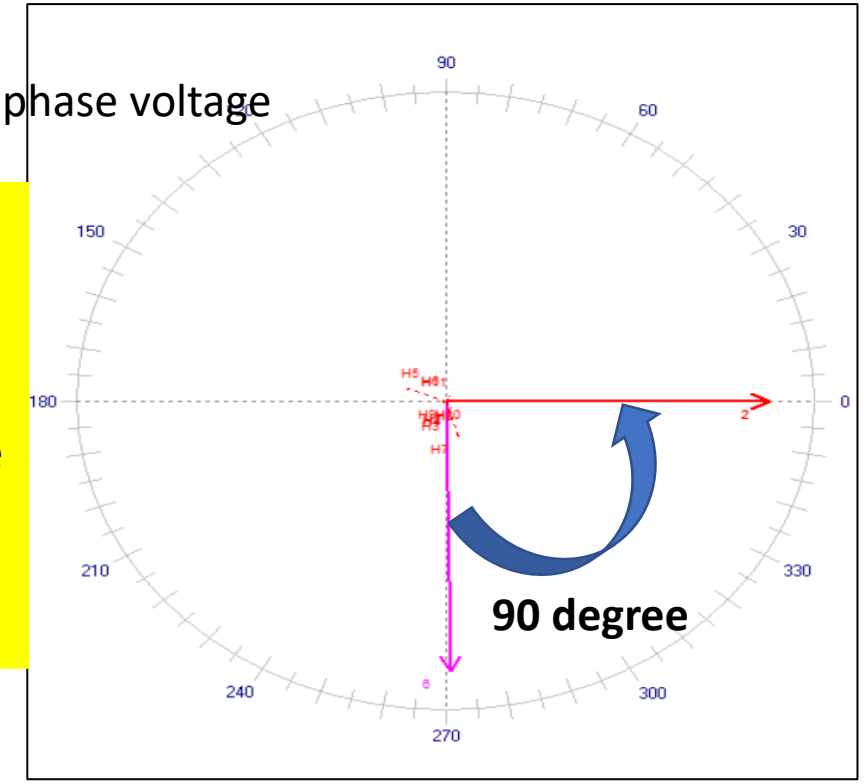
Continue..

- After the conductor is snapped and before it touched earthed object the current flowing in the broken conductor is charging current and led voltage by 90 degree. This also confirms conductor snapping.



Phasor 2 is current and phasor 6 is phase voltage

It can be seen that current and voltage is having 180 degree prior to conductor break and as soon as it is broken the current is leading voltage by 90 degree

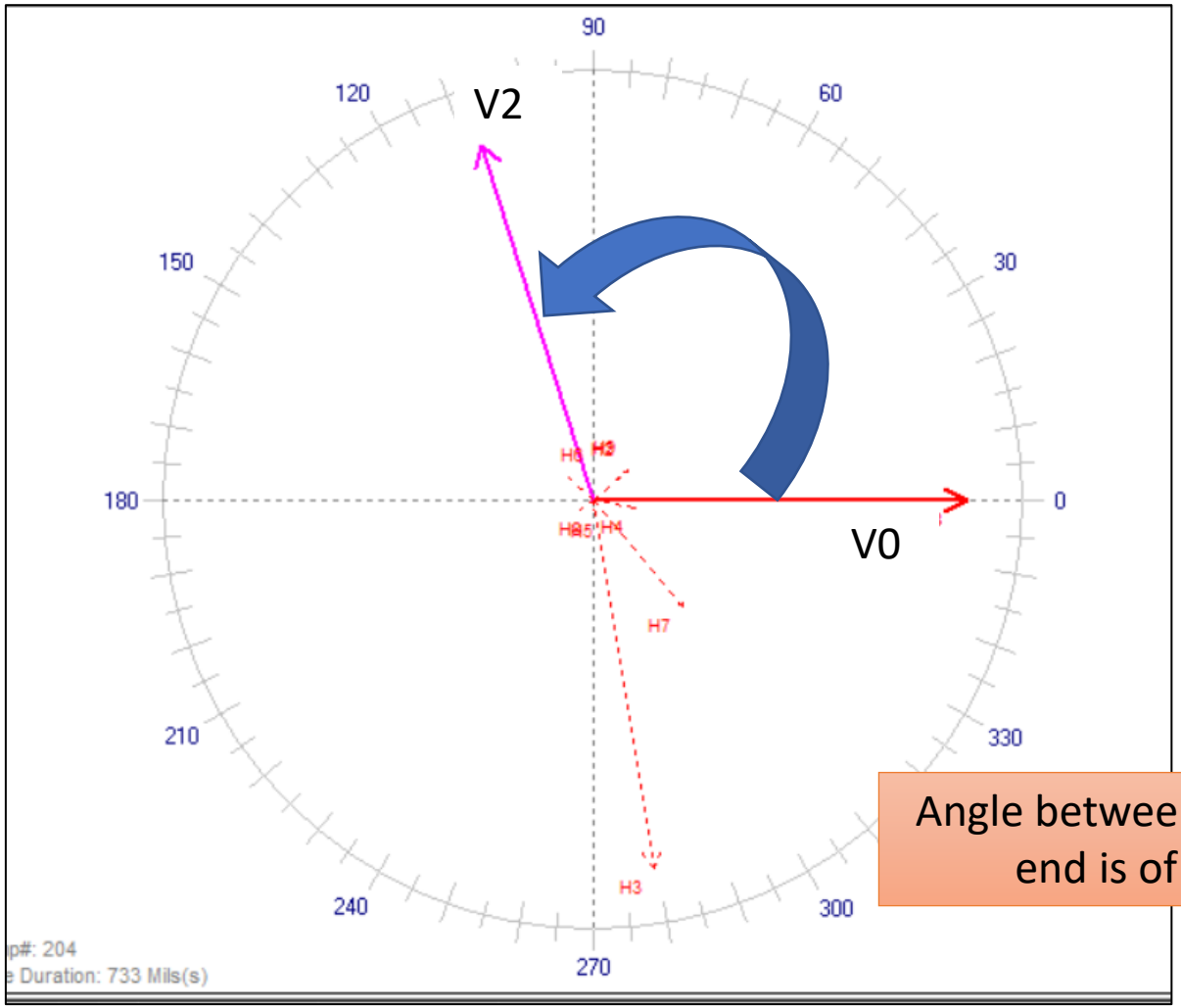


Prior to conductor snap

After conductor snap

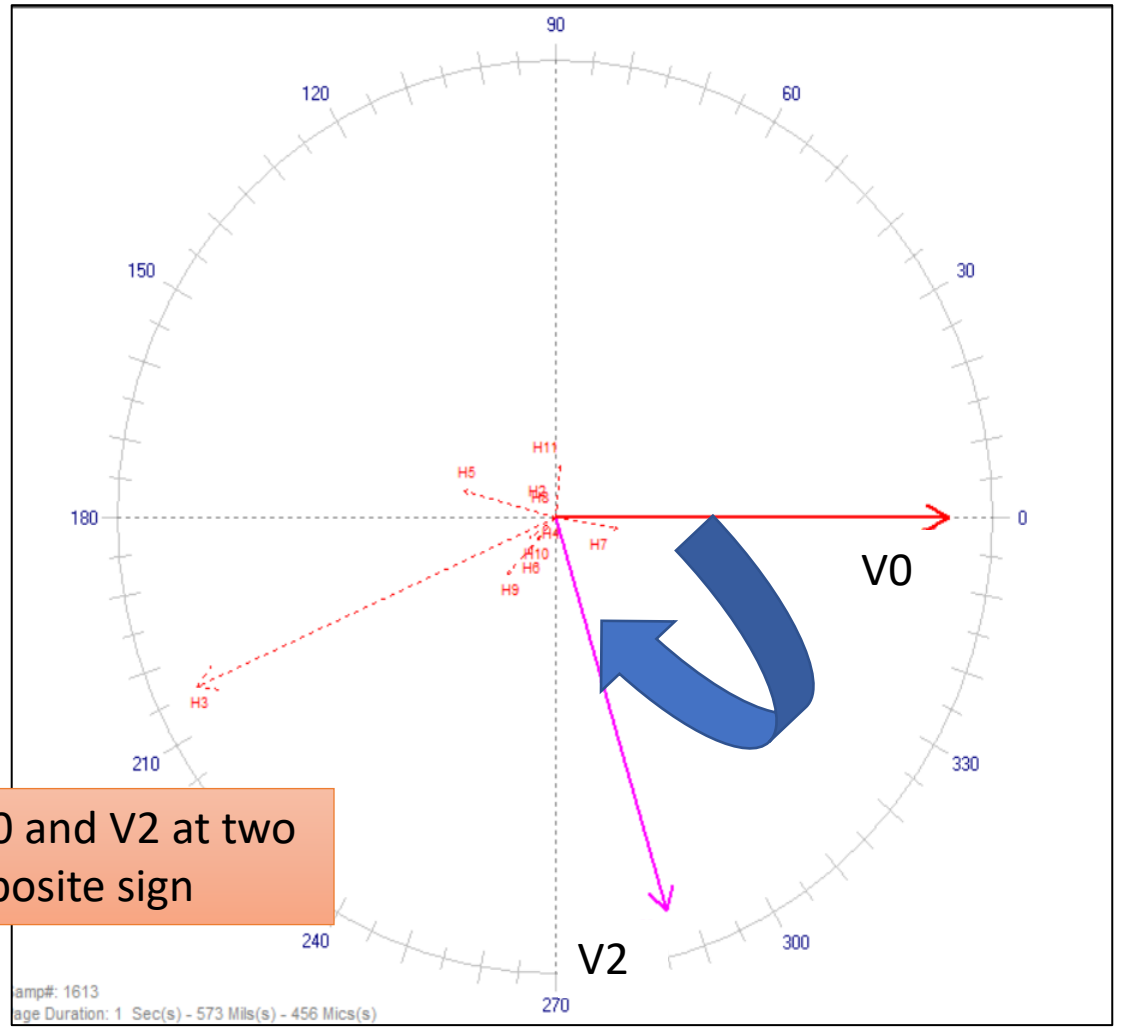
Case study: Tripping of 220 kV line on 30-11-2022 at 05:07 hrs

- V0 and V2 angle:



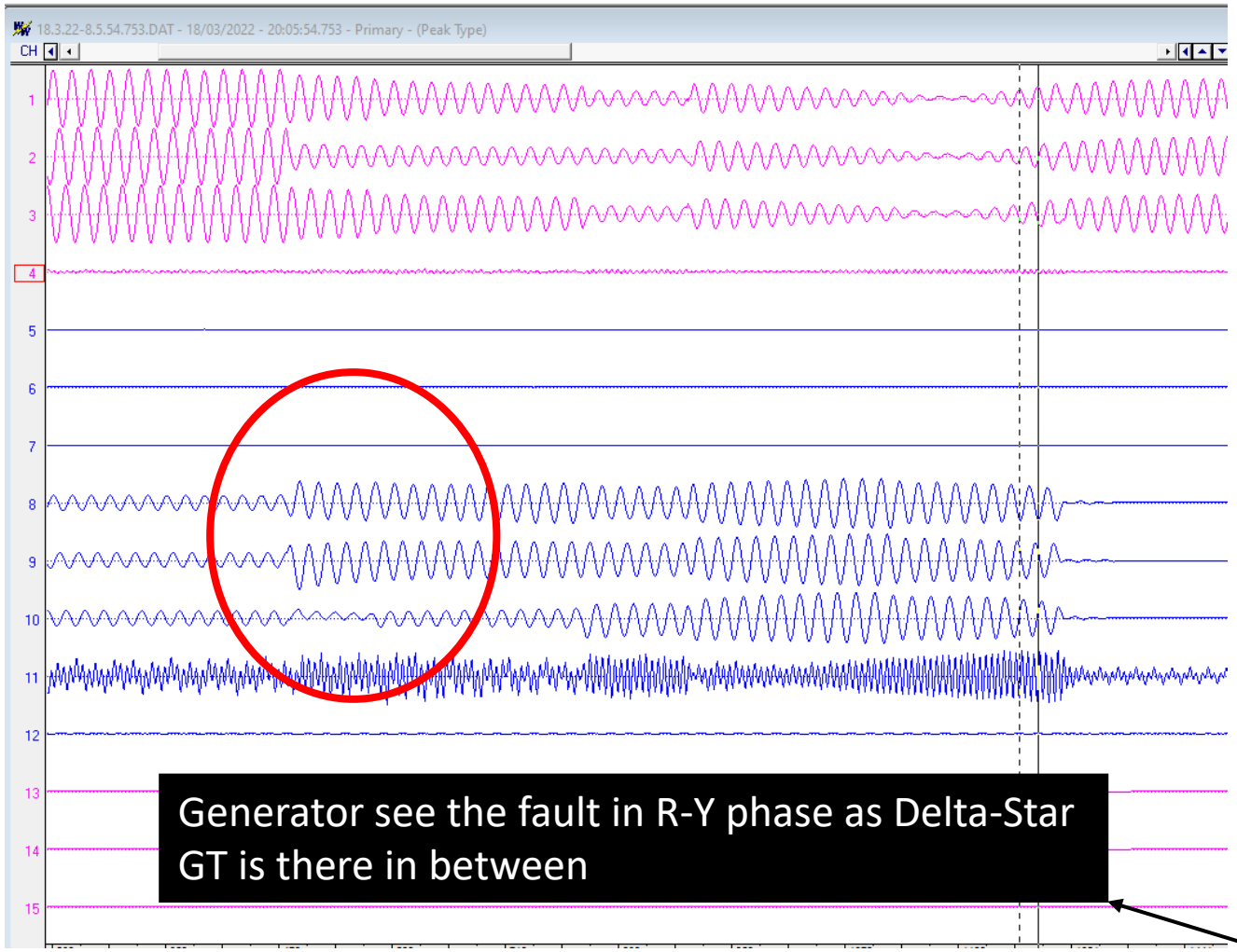
End 1

Angle between V0 and V2 at two end is of opposite sign

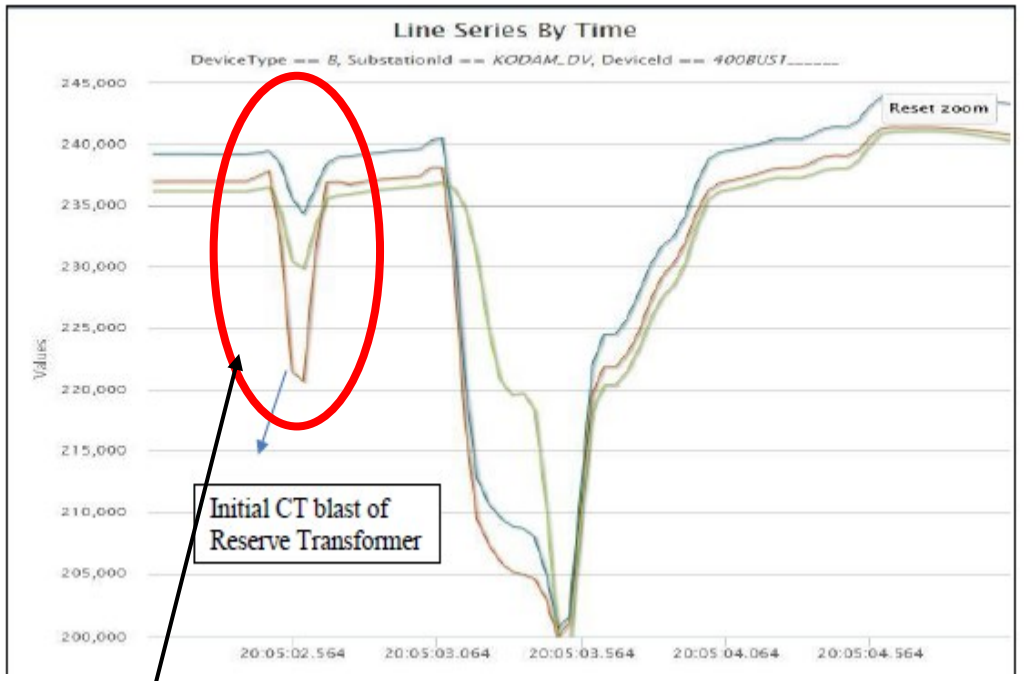


End 2

Generator Relay

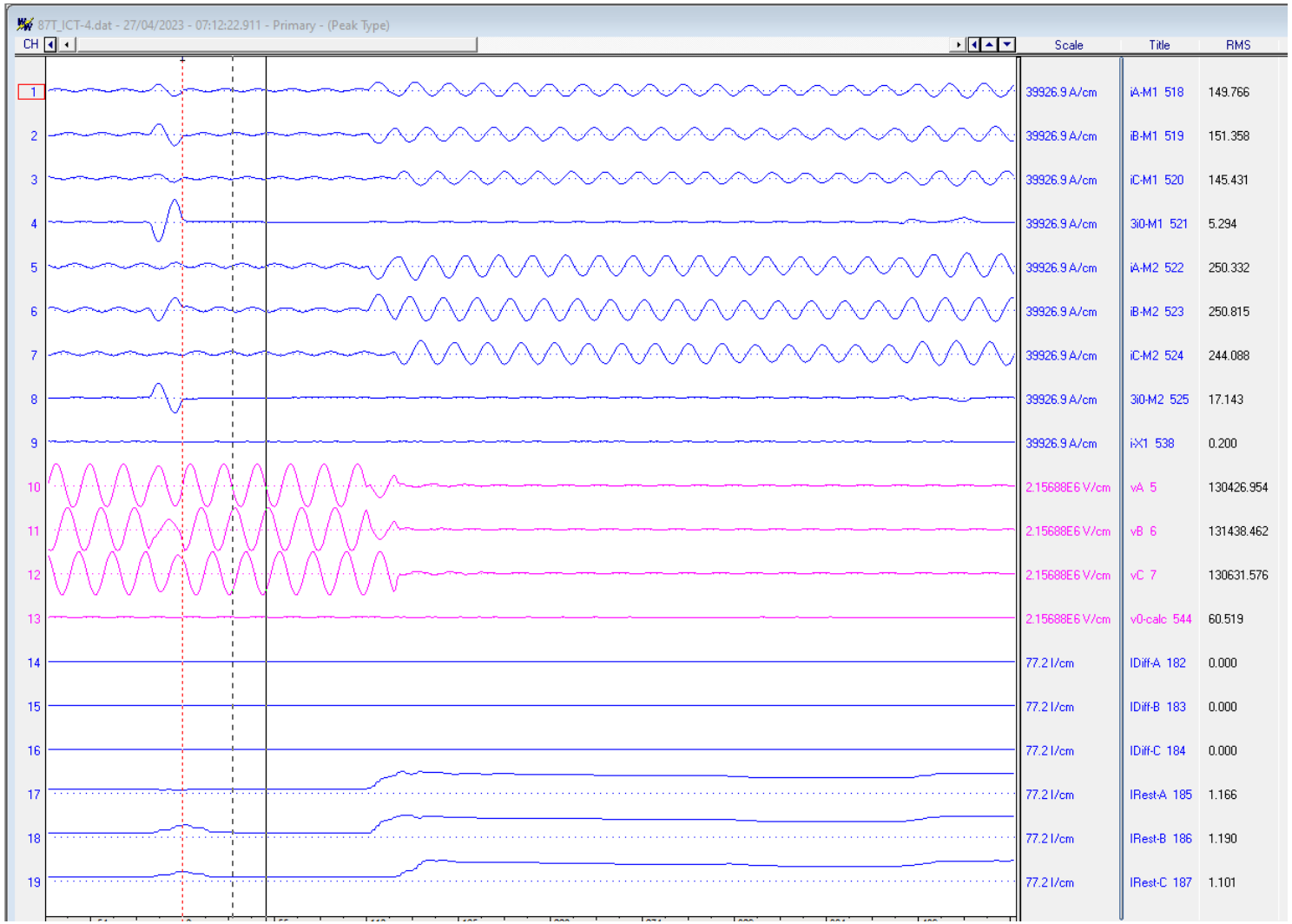


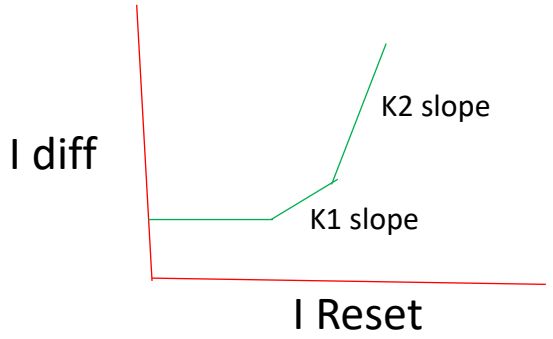
Generator see the fault in R-Y phase as Delta-Star GT is there in between



In Grid side single phase R-E fault

Transformer Differential Relay





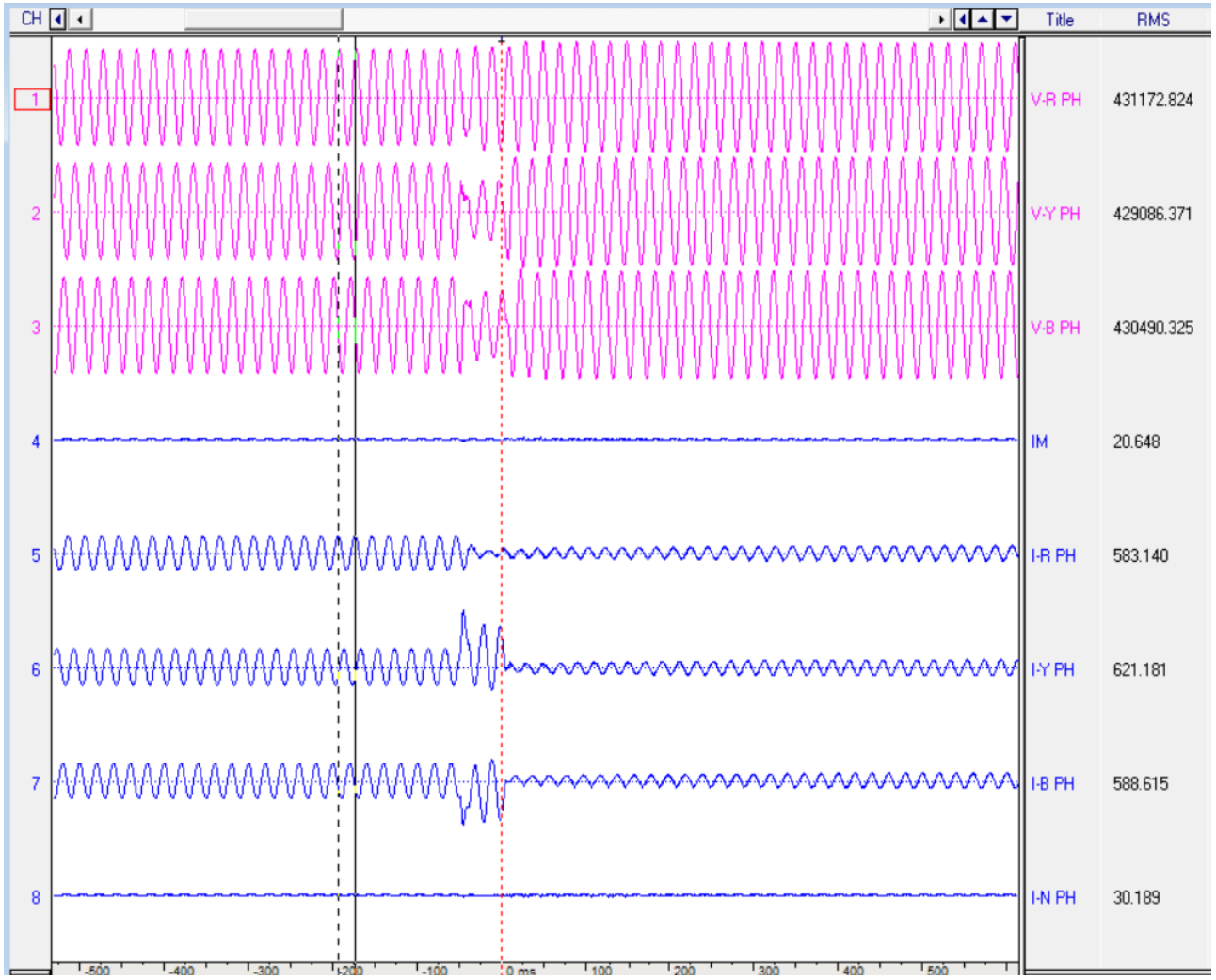
$$I_{ph\_diff} = \left| \sum_{n=1}^{N} I_{ph} \right|$$

N is number of port

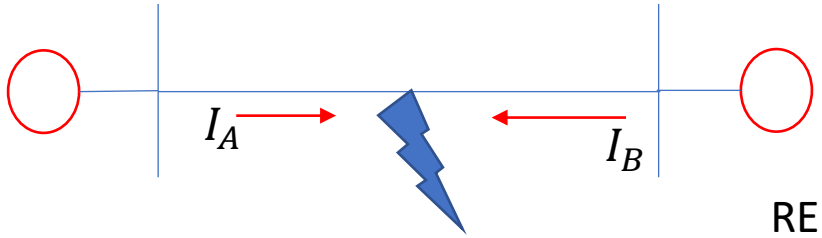
$$I_{ph\_Bias} = \sum_{n=1}^{N} |I_{ph}|$$

This is out side fault that's why I_{ph_diff} =0
However I_{ph_Bias} is high.
But no differential operation

Tripping in RE Complex



During fault No significant increase in current from the End where only RE is Connected



Current from This end
very less.
This is typical signature,
This field is evolving and lot to learn yet