Softstuf, Inc.

Line Groups and Fault Location
Technical Description Document, Revision 7 – 01/12/2017

1.0 – Line Groups

1.1) Definition:

A Line Group is a set of fields that identify the analog and digital channels of a specific line in a specific DME (Disturbance Monitoring Equipment) such as a Digital Fault Recorder (DFR), or a Sequence of Events Recorder (SOE) or a digital relay. The fields are used for identifying the line's three phase currents and voltages and associated events, and other related information such as line length, impedance, and remote end identification.

1.2) Purpose:

The process of preparing DME data for analysis is time consuming. The process includes selection, conversion, validation, alignment, calculation and merging of analog and digital data channels. Typically 45 minutes of each analysis hour is spent preparing data.

The purpose for Line Groups is to automate the process of preparing data by using templates and scripts as defined in this document. The successful use of Line Groups results in significant reductions in the time it takes to prepare data for analysis (from minutes to seconds), and enables automatic analysis and report generation features which include health checks and fault location reports.

1.3) Contents:

- Sections 1.4 thru 1.8: Format and filename details, examples, limitations, and software calculated channels
- Sections 1.9 and 1.10: Installation and usage
- Section 2: Scripts formats and report files (manual and automatic application)
- Section 3: Automatic processing and reporting architecture
- Section4: Contact information

1.4) Format:

For each DME, a text file is used to list all of the monitored lines/feeders. Each feeder in the list is a Line Group. The fields that define a Line Group are shown in Table 1.1.

Field	Description	Format
LINENAME	Line/Feeder Designation	Text (up to 12 Characters)
REMOTEDME	Remote DME Designation	Text (up to 24 Characters)
REMOTENAME	Remote Line/Feeder Designation	Text (up to 12 Characters)
VACHAN	VA Analog Channel Number	Integer Number (1 to 255)
VBCHAN	VB Analog Channel Number	Integer Number (1 to 255)
VCCHAN	VC Analog Channel Number	Integer Number (1 to 255)
IACHAN	IA Analog Channel Number	Integer Number (1 to 255)
IBCHAN	IB Analog Channel Number	Integer Number (1 to 255)
ICCHAN	IC Analog Channel Number	Integer Number (1 to 255)
INCHAN	Neutral Analog Channel Number	Integer Number (1 to 255)
BREAKER1	Digital Channel # – Breaker 1 Status	Integer Number (1 to 1024)
BREAKER2	Digital Channel # – Breaker 2 Status	Integer Number (1 to 1024)
EVENT1	Digital Channel # – Event 1 Status	Integer Number (1 to 1024)
EVENT2	Digital Channel # – Event 2 Status	Integer Number (1 to 1024)
EVENTN	Digital Channel # – Event N Status	Integer Number (1 to 1024)
VACOLOR	VA Channel Color	Text (Example: Red)
VBCOLOR	VB Channel Color	Text (Example: Blue)
VCCOLOR	VC Channel Color	Text (Example: Green)
IACOLOR	IA Channel Color	Text (Example: Red)
IBCOLOR	IB Channel Color	Text (Example: Blue)
ICCOLOR	IC Channel Color	Text (Example: Green)
INCOLOR	Neutral Channel Color	Text (Example: Fuchsia)
POSSEQR	Real POS SEQ Line Impedance (in ohms)	Real Num (5 Decimal Digits)
POSSEQX	Imaginary POS SEQ Line Impedance	Real Num (5 Decimal Digits)
ZEROSEQR	Real Zero SEQ Line Impedance (in ohms)	Real Num (5 Decimal Digits)
ZEROSEQX	Imaginary Zero SEQ Line Impedance	Real Num (5 Decimal Digits)
LINEMILES	Total Line Length in Miles	Real Num (2 Decimal Digits)
FROMBUS	CAPE From Bus Designation	Integer Number (up to 9999)
TOBUS	CAPE To Bus Designation	Integer Number (up to 9999)
CKTNUM	CAPE Circuit Number	Integer Number (up to 9999)

Table-1.1; Format of Line Groups File

1.5) Line Groups Filename:

The Line Groups filename is composed of the Substation name as specified in the COMTRADE configuration file (CFG) plus the extension ".LNG". For the CFG file shown in Figure 1.1 the Substation name is "West 49th Street" so the filename is "West 49th Street.LNG".

Figure-1.1; COMTRADE Configuration file showing the Substation Field is highlighted

1.6) Line Groups File Example:

Figure 1.2 shows the Line Group definition for one of the Feeders listed in the configuration file shown in Figure 1.1.

Figure-1.2; Line Groups File Contents Example

1.7) Structural Limits:

For Wavewin, up to 16 Line Groups can be defined for each DME. Each Line Group can have up to 10 digital channels (Breakers and other Event fields) and 10 calculated channels.

1.8) Calculated Channels:

If a group contains an unmonitored neutral or current phase, or if the currents are not monitored but can be calculated from the vector sum of breaker currents, then the definitions may include script instructions to reproduce the unmonitored phases:

- *Example 1:* If the phase currents are channels 1, 2, and 3 then the INCHAN field can be calculated using the script instruction +1/+2/+3/u=Amps/.

- *Example 2:* If the breaker channels for A phase currents are 7 and 24 then the IACHAN field can be calculated using the script instruction +7/+24/u=Amps/.

1.9) Installation:

To install Line Groups files:

- *Step-1) Save:* Create a folder (preferably a shared folder on a network drive for access by other users) and then copy the Line Groups files to it.

- *Step-2) Point:* Run Wavewin and select "Driver Configuration" from the "Options" menu in the file manager as shown in Figure 1.3, then select COMTRADE from the Drivers list and point to the new folder in the Header Directory field as shown in Figure 1.4.
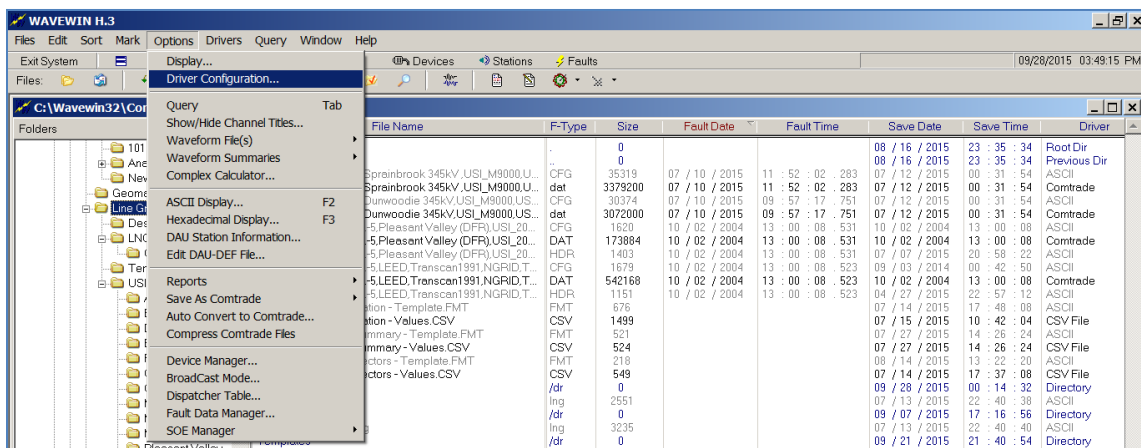
Figure-1.3; Selecting the Driver Configuration Dialog
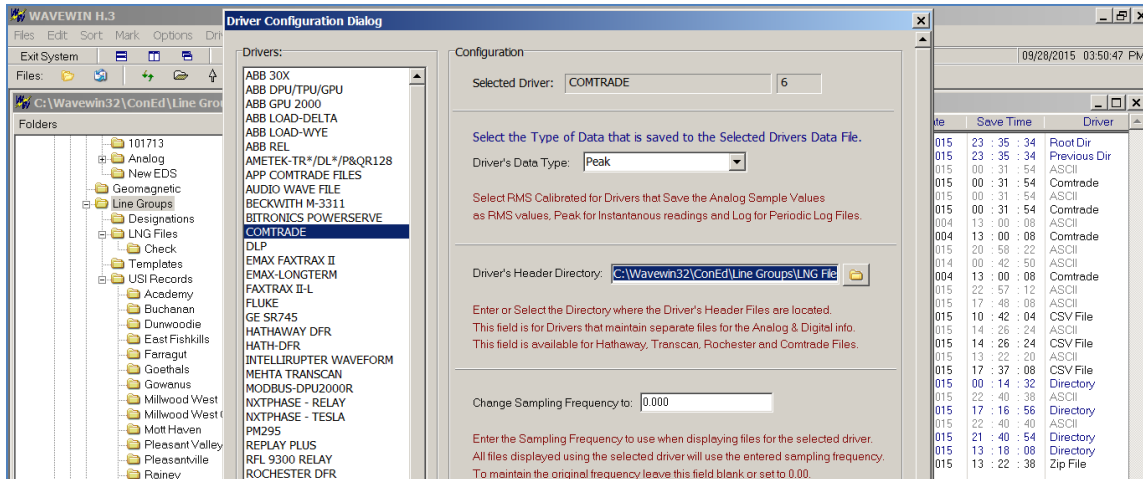
Figure-1.4; Pointing to the Line Groups files (Driver's Header Directory)

1.10) Using Line Groups:

Run Wavewin and open a fault record from a DME. Click on the list indicator of the ALL icon as shown in Figure 1.5, and then select a Feeder designation to view its channels as shown in Figure 1.6. Mouse-over the ALL icon to see the designation of the selected Feeder.
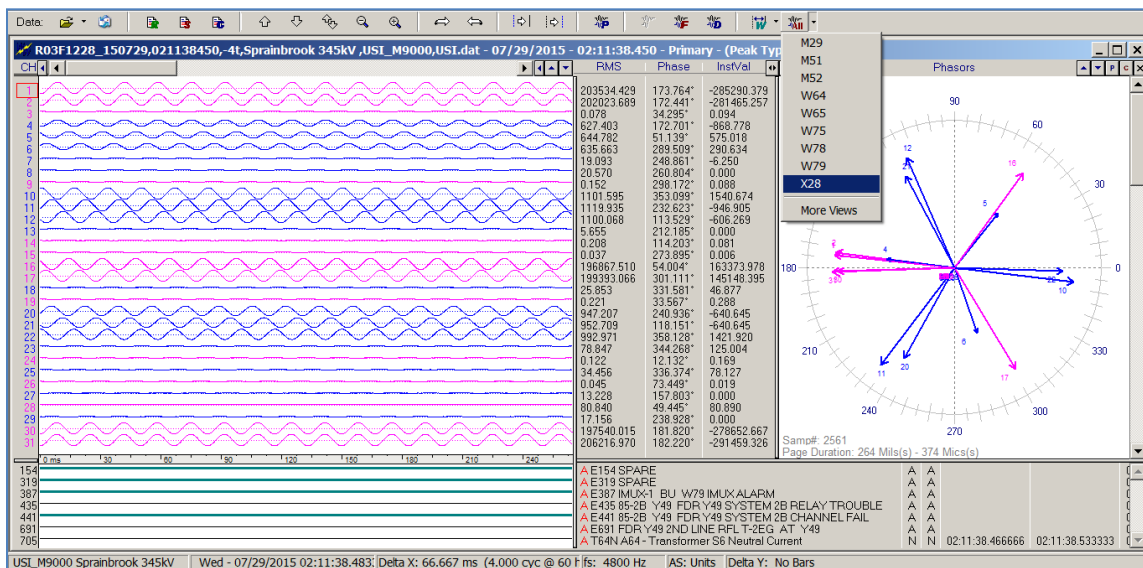
Figure-1.5; Selecting a Line Group to View for Manual Analysis
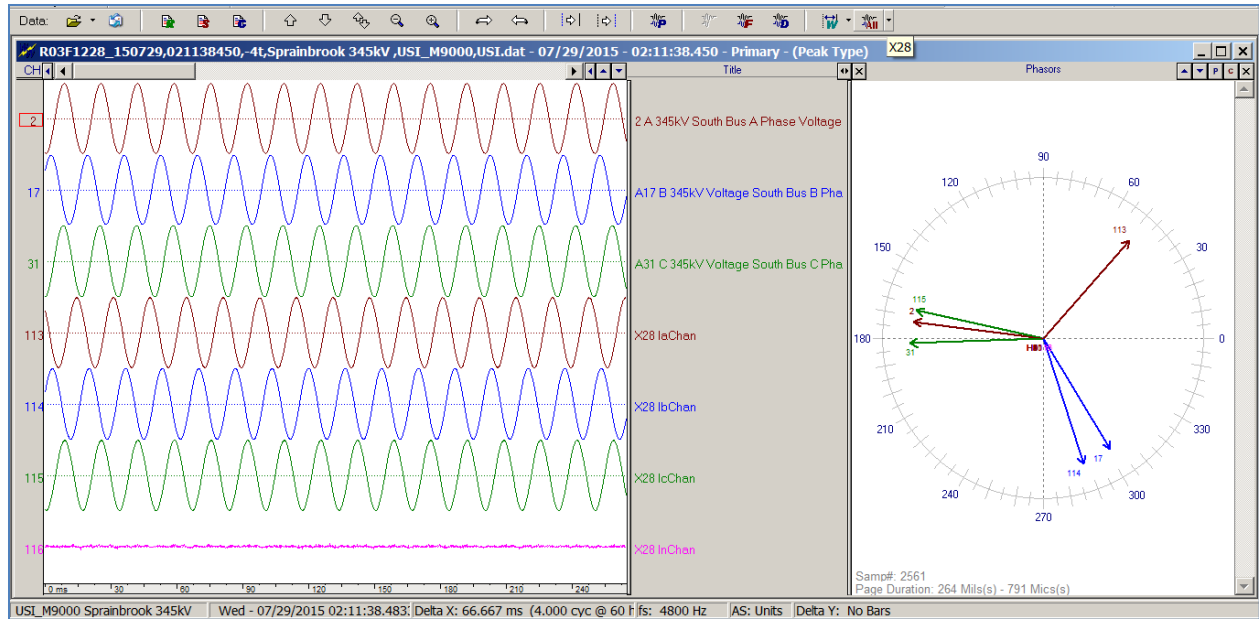
Figure-1.6; Waveform Display Showing the Selected Line Group

2.0 – Scripts and Report Files

2.1) Format:

Multiple types of report files can be created including for example health checks and fault location reports. To simplify the process of creating various types of reports, script instructions are used for defining and formatting reports. This allows users to modify or create new reports without having to upgrade the Software.

Script instructions are enclosed in reserved characters: < > [ ]. The instructions are inserted in user created text files. The < > characters are used to define fault quantities and [ ] are used to define prefault quantities. For example, the following script sequence:

- DME Name: <Station>
- Feeder: <Line>
- Fault Time: <Date> - <Time>
- VA Prefault: [^1:R][^1:U] at [^1:P] Degrees
- VA Fault: <^1:R><^1:U> at <^1:P> Degrees

Produces the following text sequence:

- DME Name: Mott Haven

- Feeder Name: 71
- Fault Time: 07/27/2015 - 10:31:41.383333
- VA Prefault: 342206.042 V at 243.004 Degrees
- VA Fault: 299962.322 V at 248.203 Degrees

Files containing such script instructions are template files that are used with Line Groups to produce custom reports.

2.2) Manual Application:

Here are the steps to manually apply a script template to a selected DME record:

- ***Step-1) Select Feeder:*** Run Wavewin and open a DME fault record and then select the desired Feeder from the Line Groups list as shown in Figures 1.4 and 1.5.

- ***Step-2) Select Template:*** Select the "Mark and Save" window from the "Values" menu option as shown in Figure 2.1 and then use the highlighted browse button as shown in Figure 2.2 (red circle) to select the desired template containing the user script instructions. If the template has not been created yet, then specify a filename in the top window, create the script template, and then click the Save button.

- ***Step-3) Apply Template:*** To apply the template, position the solid black data bar in the fault area, then position the dashed blue reference bar in the prefault area, and then click on the Mark button at the bottom of the "Mark and Save" window (red circle) to create the custom report as shown in Figure 2.3.
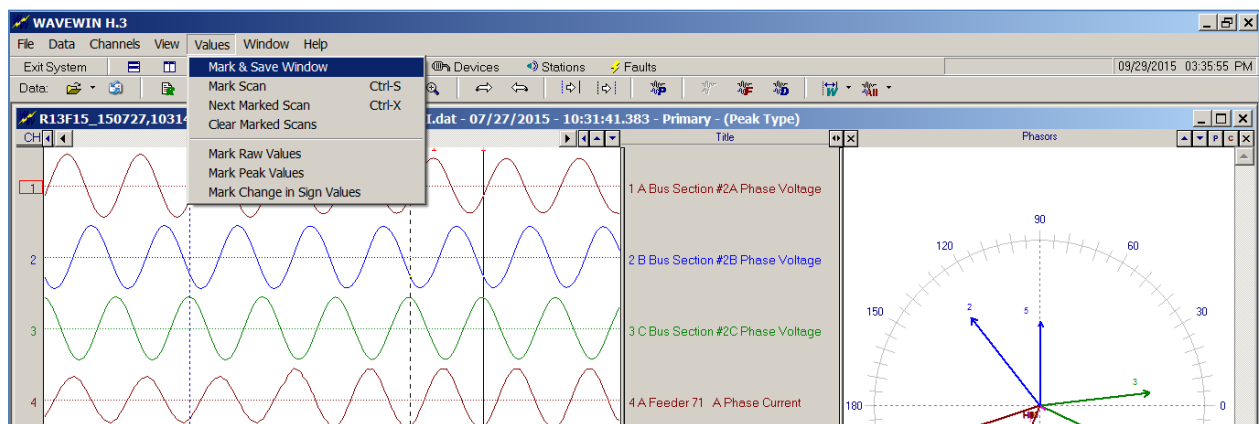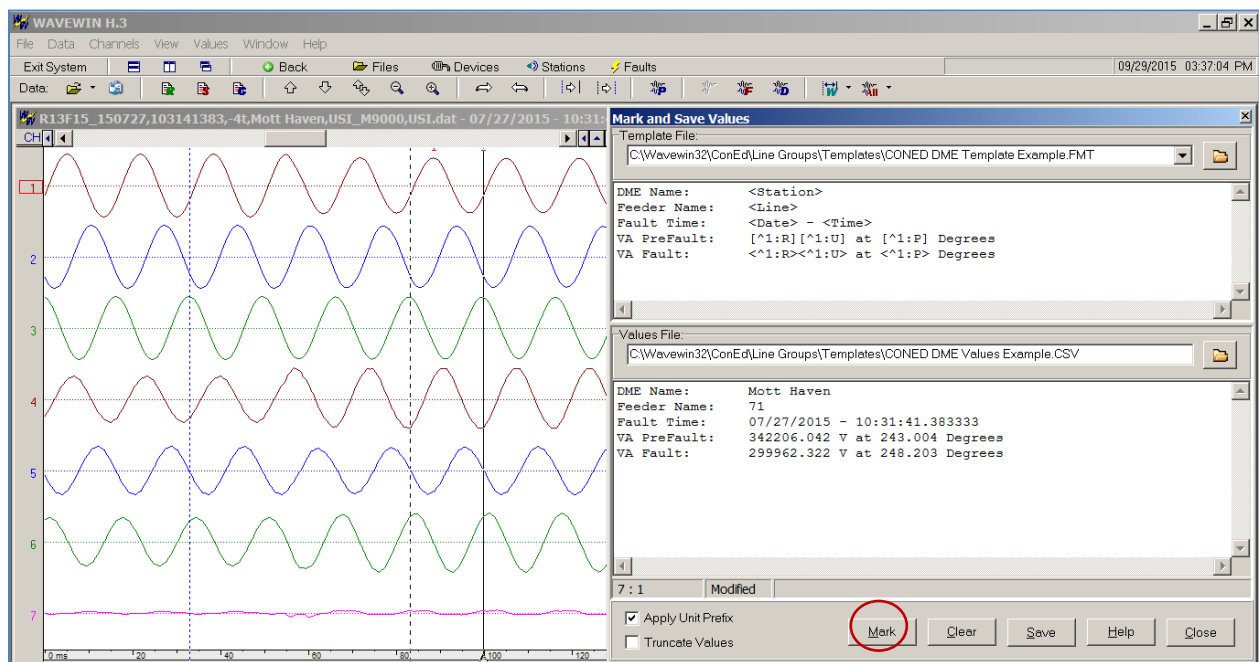

Figure-2.1; Selecting the Mark and Save Window for Creating Custom Reports
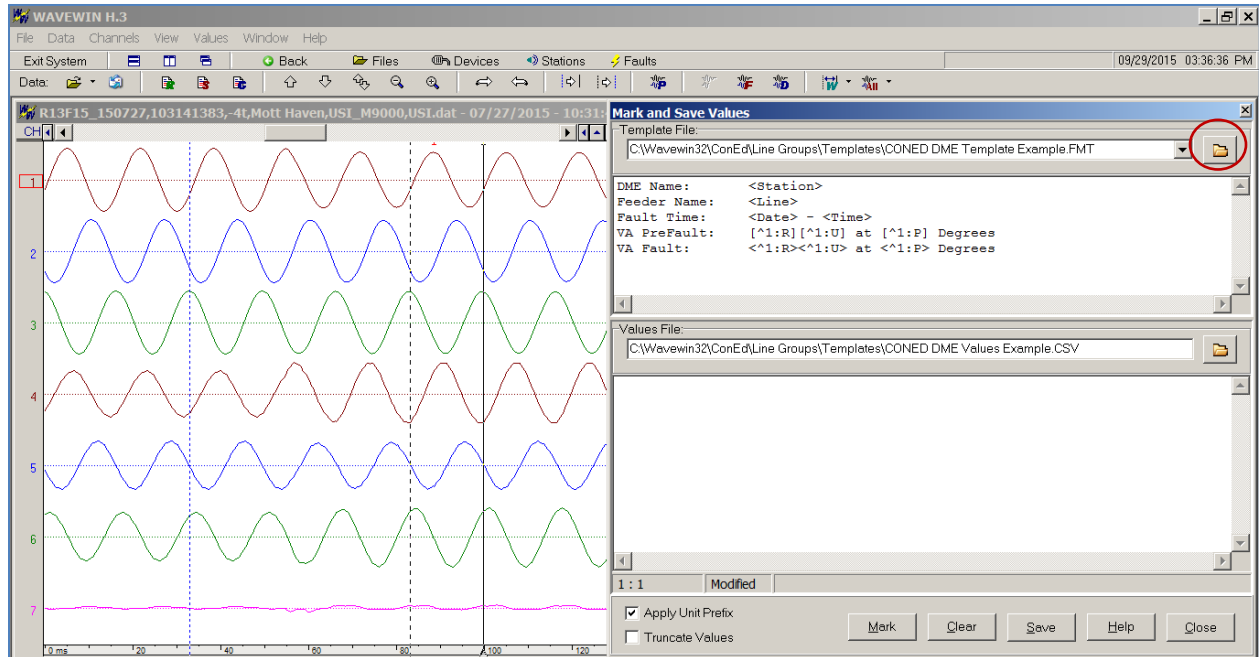
Figure-2.2; Selecting the Desired Template for Creating Custom Reports

Figure-2.3; Resulting Custom Report from the Mark and Save Window

2.3) Automatic Application:

Command line parameter are used to invoke Wavewin to open a DME record, select a Feeder from its Line Groups, select a user template with script instructions, and then create the custom report (all automatically).

The command line parameters are included in a text file named "FLREPORT.RUN". The contents of the parameters file are shown in Table 2.1:

Field	Description	Format
DME Record	Path and filename of DME record	Text (up to 128 Characters)
/Line	Feeder from the DME Line Groups	Text (up to 12 Characters)
/ Template	Path and filename of template file	Text (up to 128 Characters)
/Exit	Command to close when complete	Text (Fixed)

Table-2.1; FLREPORT.RUN Contents for Automatic Creation of Custom Reports

Once the parameters file is created, Wavewin can be invoked with the following command line:

Drive:\Program Path\Wavewin32.exe "Template Path\FLREPORT.RUN" /Batch

Where,

Drive: Is the drive letter where Wavewin is located.
Program Path: Is the path where Wavewin is located.
Template Path: Path where the template is located and where the custom report is saved.
Batch: Command that tells the system to process multiple sets of line parameters.

Once Invoked with the /Batch command, Wavewin will open the FLREPORT.RUN file and iterate through all of the listed sets of command line parameters. For each set, Wavewin will perform the following steps (automatically):

- Open the specified DME record.
- Select the specified Feeder.
- Open the specified template with script instructions.
- Apply the specified template and save the resulting custom report.
- Proceed to the next set of command line parameters and repeat the above steps.
- Close Wavewin when complete.

The resulting custom report is saved as a text file in the template path. The report file is named in line with IEEE Std. C37.232 (COMNAME) with a DIG extension:

Date Report was Created, Time Report was Created, Name of Template File.DIG

2.4) Automatic Application Example:

An example of the FLREPORT.RUN command parameters file is shown in Figure 2.4.

Figure-2.4; Example of the FLREPORT.RUN Command Parameters File

The file lists multiple folders with DME records. The "*.DAT" wild card at the end of the first parameter tells Wavewin to process all of the COMTRADE DME records in that folder. The "/Line=ALL" parameter tells Wavewin to apply all of the Line Groups for each DME record. The "/Template=" parameter points Wavewin to the path and filename of the script template to apply. The "/Exit" parameter tells Wavewin to close the DME record when complete.

The name of the template file is up to the user and a different template may be used with each entry in the FLREPORT.RUN file. The template file used in this example is named "Vectors.FMT". The contents of the template file are shown in Figure 2.5.

Figure-2.5; Example of the Template File with Script Instructions

Once invoked with the command line parameter:

C:\Wavewin32\Wavewin32.exe "C:\Wavewin32\ConED\Reports\FLREPORT.RUN" /Batch

Wavewin will automatically iterate through all of the specified DME records and Line Groups and apply the specified templates. A snap shot of one step in the process is shown in Figure 2.6.
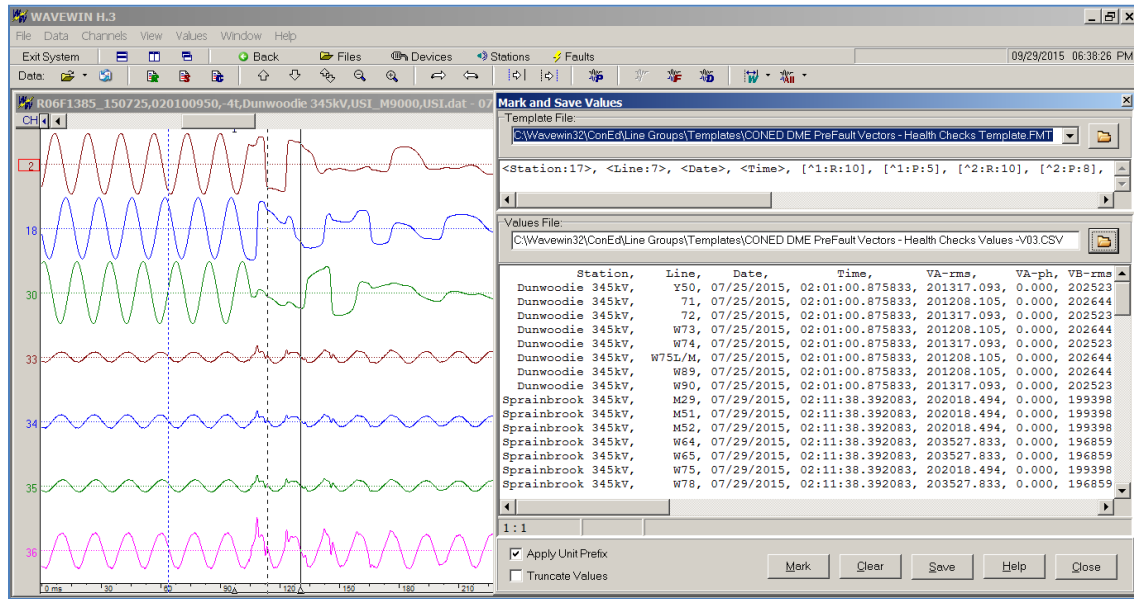

Figure-2.6; Snap Shot of Wavewin Iterating through DME Records and Feeders

When all of the specified DME records and Line Groups have been processed, Wavewin will save the resulting custom report to the same path where the FLREPORT.RUN file was specified. Figure 2.7 shows the resulting custom report.
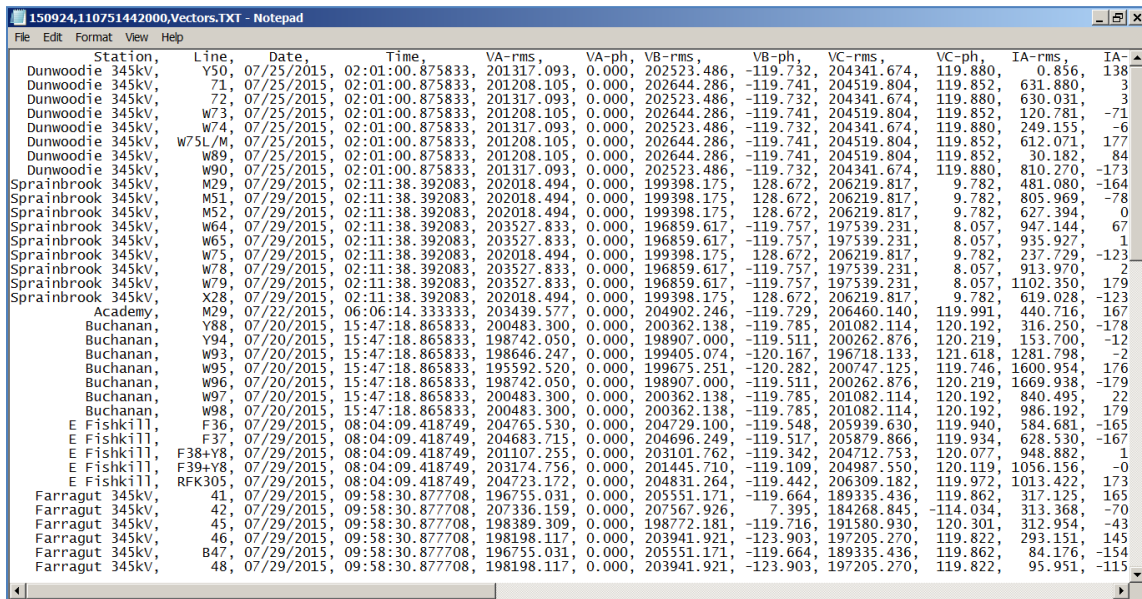
Figure-2.7; Resulting Custom Report

3.0 – Automatic Processing and Reporting Architecture

DME X Line Groups

DME Fault Record

Fault Record from DME X

Feeder X1
:
Feeder XN

Report Templates

Another Record from DME X

User Report 1
:
User Report 2

DME Y Line Groups

Fault Record from DME Y
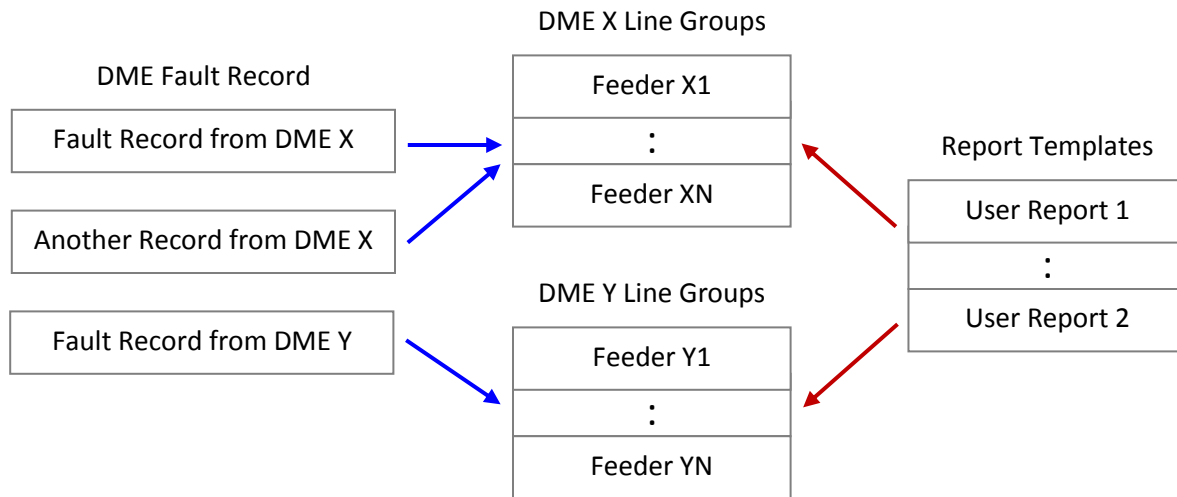
Feeder Y1
:
Feeder YN

Figure-3.1; High Level Architecture of the 3D Automation System Design

For each DME a number of Feeders are defined and for each Feeder a number of Reports are defined. This provides a many to many, three-dimensional (3D) architecture where: The first dimension is the DME, the second dimension is the Feeder, and the third dimension is the Report (a graphical depiction is provided in Figure 3.1).

The main function of Wavewin in this project is to automatically navigate the 3D architecture as an assembly line, meaning:

- *Step 1:* Recognize that a new DME record has been received.
- *Step 2:* Read/open the DME record (using COMTRADE format).
- *Step 3:* Apply the first/next defined Feeder for that DME.
- *Step 4:* Apply the first/next defined Report for that Feeder.
- *Step 5:* Repeat Step 4 until all of the Reports have been applied for that Feeder.
- *Step 6:* Repeat Step 3 until all of the Feeders have been applied for that DME.
- *Step 7:* Save/Archive all of the resulting Reports.
- *Step 8:* Mark the DME record as being processed (using COMNAME user fields).
- *Step 9:* Repeat (restarting at Step 1).

The objective is to unlock Giga Bytes of DME data and reduce to Kilo Bytes of information by extracting/calculating a sufficient set of key measurements to enable automation. The sufficient set of key measurements is defined by the default Report. The default Report includes script

commands to extract prefault and fault vectors, calculate unbalances, and save the resulting key measurements as a spreadsheet. The script commands provided with the default Report template are detailed in Table 3.1.

Script Command	Description	Format
<Station:17>	DME Station Name	Text (up to 17 Characters)
<Line:7>	DME Feeder Name	Text (up to 7 Characters)
[Date]	Date of Prefault Vectors	Date (Standard Format)
[Time]	Time of Prefault Vectors	Time (Standard Format)
[^1,^2,^3:B:6]	Prefault Voltages – Magnitude Unbalance	Numeric (6 digits)
[^4,^5,^6:B:6]	Prefault Currents – Magnitude Unbalance	Numeric (6 digits)
[^1,^2,^3:S:6]	Prefault Voltages – Phase Unbalance	Numeric (6 digits)
[^4,^5,^6:S:6]	Prefault Currents – Phase Unbalance	Numeric (6 digits)
[^1:R:10]	Prefault Vectors – VA RMS Magnitude	Numeric (10 digits)
[^1:P:6]	Prefault Vectors – VA Phase Angle	Numeric (6 digits)
[^2:R:10]	Prefault Vectors – VB RMS Magnitude	Numeric (10 digits)
[^2:P:8]	Prefault Vectors – VB Phase Angle	Numeric (8 digits)
[^3:R:10]	Prefault Vectors – VC RMS Magnitude	Numeric (10 digits)
[^3:P:8]	Prefault Vectors – VC Phase Angle	Numeric (8 digits)
[^4:R:8]	Prefault Vectors – IA RMS Magnitude	Numeric (8 digits)
[^4:P:8]	Prefault Vectors – IA Phase Angle	Numeric (8 digits)
[^5:R:8]	Prefault Vectors – IB RMS Magnitude	Numeric (8 digits)
[^5:P:8]	Prefault Vectors – IB Phase Angle	Numeric (8 digits)
[^6:R:8]	Prefault Vectors – IC RMS Magnitude	Numeric (8 digits)
[^6:P:8]	Prefault Vectors – IC Phase Angle	Numeric (8 digits)
[^7:R:8]	Prefault Vectors – IN RMS Magnitude	Numeric (8 digits)
[^7:P:8]	Prefault Vectors – IN Phase Angle	Numeric (8 digits)
<Date>	Date of Fault Vectors	Date (Standard Format)
<Time>	Time of Fault Vectors	Time (Standard Format)
<^1,^2,^3:N:6>	Fault Voltages – Negative Sequence	Numeric (6 digits)
<^4,^5,^6:N:6>	Fault Currents – Negative Sequence	Numeric (6 digits)
<^1:R:10>	Fault Vectors – VA RMS Magnitude	Numeric (10 digits)
<^1:P:6>	Fault Vectors – VA Phase Angle	Numeric (6 digits)
<^2:R:10>	Fault Vectors – VB RMS Magnitude	Numeric (10 digits)
<^2:P:8>	Fault Vectors – VB Phase Angle	Numeric (8 digits)

<^3:R:10>	Fault Vectors – VC RMS Magnitude	Numeric (10 digits)
<^3:P:8>	Fault Vectors – VC Phase Angle	Numeric (8 digits)
<^4:R:8>	Fault Vectors – IA RMS Magnitude	Numeric (8 digits)
<^4:P:8>	Fault Vectors – IA Phase Angle	Numeric (8 digits)
<^5:R:8>	Fault Vectors – IB RMS Magnitude	Numeric (8 digits)
<^5:P:8>	Fault Vectors – IB Phase Angle	Numeric (8 digits)
<^6:R:8>	Fault Vectors – IC RMS Magnitude	Numeric (8 digits)
<^6:P:8>	Fault Vectors – IC Phase Angle	Numeric (8 digits)
<^7:R:8>	Fault Vectors – IN RMS Magnitude	Numeric (8 digits)
<^7:P:8>	Fault Vectors – IN Phase Angle	Numeric (8 digits)
<BX:S>	Breaker X Status (Normal/Abnormal)	Text (1 characters)
<BX:D>	Breaker X Start Time (with Milliseconds)	Time Tag (27 characters)
<BX:E>	Breaker X End Time (with Milliseconds)	Time Tag (27 characters)
<BX:T>	Breaker X Report (Name, Time, Duration)	Summary (up to 80 Chars)
<EX:S>	Event X Status (Normal/Abnormal)	Text (1 characters)
<EX:D>	Event X Start Time (with Milliseconds)	Time Tag (27 characters)
<EX:E>	Event X End Time (with Milliseconds)	Time Tag (27 characters)
<EX:T>	Event X Report (Name, Time, Duration)	Summary (up to 80 Chars)
<Z1M:8>	Magnitude Positive Seq Line Impedance	Numeric (8 digits)
<Z1P:8>	Angle Positive Seq Line Impedance	Numeric (8 digits)
<Z0M:8>	Magnitude Zero Seq Line Impedance	Numeric (8 digits)
<Z0P:8>	Angle Zero Seq Line Impedance	Numeric (8 digits)
<LL:8>	Total Line Length in Miles	Numeric (8 digits)
<FBUS>	CAPE From Bus Designation	Integer (up to 9999)
<TBUS>	CAPE To Bus Designation	Integer (up to 9999)
<CKTN>	CAPE Circuit Number	Integer (up to 9999)
<RDME>	Remote DME Station Name	Text (up to 24 Characters)
<REMOTE>	Remote Feeder Name	Text (up to 12 Characters)

Table-3.1; Script Commands of the Default Report Template

All of the values needed for automation are defined by the above 58 script commands. The commands provide measurements of prefault and fault vectors for both voltage and current phases. They also include impedance and length values needed for running the single and double ended fault location algorithms.

The commands also provide functions for calculating imbalances and negative sequence, and triggers can be set for any of the calculations using L for less than or G for greater than. For example the command ^7:RG1250 will produce the text Alarm if the neutral current magnitude is over 1250 Amps RMS otherwise it will produce the text Normal.

The values resulting from running the script commands are saved to a text file. The text file format is comma separated (the script values are separated by commas and the last value is followed by a <CR/LF> as shown in Figure 2.7). With this format the key measurements for each line appear in a separate row.

4.0 – Contact Information

For questions and/or additional information, please contact:

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