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# Festus, MO 63028

# ETAP SIMULATION

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# TABLE OF CONTENTS




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# 1. GENERAL

## 1.1 Purpose of this Study

The purpose of this study is to check the harmonic distortion at the Point of Common Coupling in compliance with IEEE 519 guidelines. This study is based on available data as indicated in the next section. The system simulation has been performed using ETAP Software Version 5.5.6

## 1.2 Data Available

Following document was available for this study:

| | |
|---|---|
| Power Distribution Diagram Main One-Line | C06130 E PS 8400 00 1 of 1 |


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## 1.3 Assumptions

Following the data specified above and having installed the one line diagram on ETAP, the following assumptions were made:

Utility Isc = 2.09 kA sym. @ 138 kV 500 MVA 3-ph
Tie-breakers Status Open

**Harmonic Injection - Rockwell Drives**

| | 6-pulse | | 12-pulse | | 18-pulse | |
|---|---|---|---|---|---|---|
| | Ampl. | Angle | Ampl. | Angle | Ampl. | Angle |
| 0 | 0.16 | 58.00 | 0.95 | 111.00 | 0.28 | 112.00 |
| 1 | 0.59 | 121.00 | 3.62 | -135.00 | 0.89 | -84.00 |
| 2 | 0.12 | 44.00 | 0.14 | 113.00 | 0.00 | 118.00 |
| 3 | 23.52 | 111.00 | 4.44 | 100.00 | 2.06 | -76.00 |
| 4 | 0.10 | 102.00 | 0.09 | -37.00 | 0.00 | 46.00 |
| 5 | 6.08 | 109.00 | 1.66 | -121.00 | 1.32 | 13.00 |
| 6 | 0.03 | 75.00 | 0.09 | 95.00 | 0.14 | 87.00 |
| 7 | 0.09 | -169.00 | 0.43 | 157.00 | 0.37 | 153.00 |
| 8 | 0.00 | 47.00 | 0.03 | -169.00 | 0.09 | 46.00 |
| 9 | 4.57 | -158.00 | 6.54 | 56.00 | 1.32 | 85.00 |
| 10 | 0.03 | -108.00 | 0.03 | 126.00 | 0.05 | -141.00 |
| 11 | 4.20 | -178.00 | 4.95 | 64.00 | 1.03 | 127.00 |
| 12 | 0.03 | 78.00 | 0.14 | 64.00 | 0.09 | 52.00 |
| 13 | 0.06 | 37.00 | 0.24 | -107.00 | 0.14 | -180.00 |
| 15 | 1.80 | -94.00 | 0.47 | 126.00 | 0.19 | 159.00 |
| 17 | 1.37 | -92.00 | 0.42 | -124.00 | 0.33 | -180.00 |
| 21 | 0.75 | -70.00 | 0.86 | 66.00 | 0.47 | 80.00 |
| 23 | 0.56 | -70.00 | 1.09 | 73.00 | 0.28 | 114.00 |
| 27 | 0.49 | -20.00 | 0.12 | -178.00 | 0.05 | 153.00 |
| 29 | 0.54 | 7.00 | 0.14 | -173.00 | 0.14 | -89.00 |

**Note**
All VFD drives are 12-pulse, with the exception of the 18-pulse 6971 HP drive.


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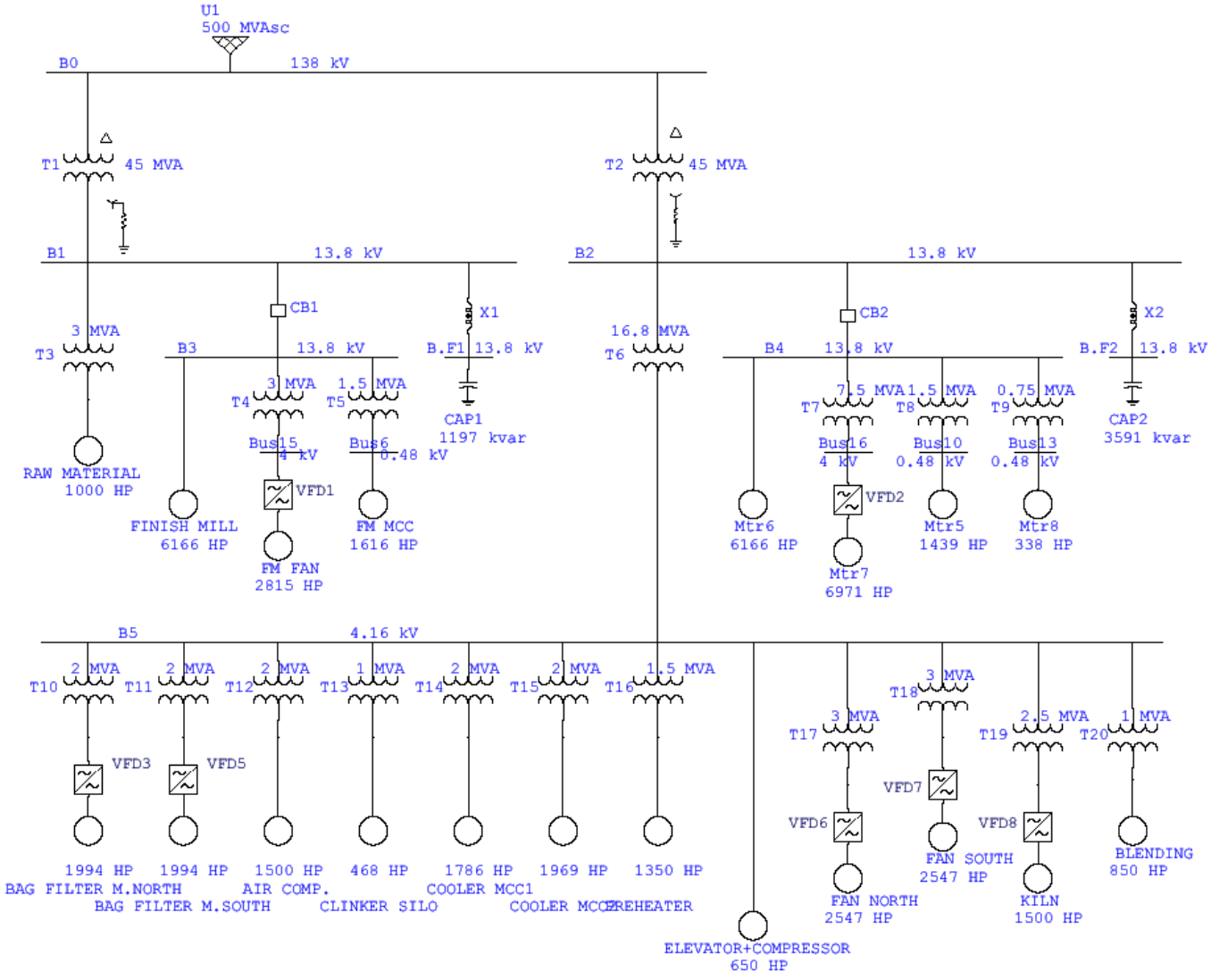
# 2. RESULTS

## 2.1 ETAP Single Line Diagram





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## 2.2 Current and Voltage Harmonics at PCC

The following table shows the % harmonic currents at the primary side of the main 45 MVA 138/13.8 kV transformers T1 and T2:

**Current Harmonics**

| | T1 | T2 | IEEE Lim % |
|---|---|---|---|
| I1 | 41.3 A | 128.4 A | |
| n = 2 | 0.0343 | 0.0444 | 7.0 |
| 4 | 0.0552 | 0.0634 | 7.0 |
| 5 | 4.8713 | 1.2380 | 7.0 |
| 7 | 1.3359 | 0.4112 | 7.0 |
| 8 | 0.0043 | 0.0074 | 7.0 |
| 11 | 0.6029 | 1.3441 | 3.5 |
| 13 | 0.5966 | 1.2343 | 3.5 |
| 14 | 0.0070 | 0.0047 | 3.5 |
| 17 | 0.3609 | 0.2146 | 2.5 |
| 19 | 0.2654 | 0.1782 | 2.5 |
| 23 | 0.1446 | 0.2079 | 1.0 |
| 25 | 0.1120 | 0.1506 | 1.0 |
| 29 | 0.0779 | 0.0914 | 1.0 |
| 31 | 0.0808 | 0.1048 | 1.0 |
| THD | 5.1463 | 2.2805 | 8.0 |

**Comment**

The above table show comfortable compliance with IEEE limits for $20 < Isc/I_L < 50$ (values in blue are compliant, values in red are not compliant)


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The following table shows the voltage harmonics at the main 138 kV bus B0:

**Voltage Harmonics**

| N | % V |
|---|---|
| 2 | 0.0059 |
| 4 | 0.0167 |
| 5 | 0.2635 |
| 7 | 0.1553 |
| 8 | 0.0041 |
| 11 | 0.9773 |
| 13 | 1.0512 |
| 14 | 0.0036 |
| 17 | 0.2734 |
| 19 | 0.2569 |
| 23 | 0.2921 |
| 25 | 0.2255 |
| 29 | 0.2010 |
| 31 | 0.2442 |
| | |
| THD-V | 1.5909 |

**Comment**

Voltage THD values are well below IEEE limit of 3% for Special Applications (worst case). Values above are on the safe side when compared with the measured average THD-V of 0.7 to 0.8 Volts / 115V (about 0.7 %).


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## 2.3 Power Factor

Considering full plant load, both filters being on and off:

| | |
|---|---|
| Filters ON | 40.6 MVA, 93.3% PF (lagging) |
| Filters OFF | 42.7 MVA, 88.6% PF (lagging) |
| Total Filter KVAR | 3,644 + 1,255 KVAR = 4,899 KVAR |


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# 3. APPENDIX

## 3.1 IEEE Guidelines

**Table 10-3—Current Distortion Limits for General Distribution Systems (120 V Through 69 000 V)**

| Maximum Harmonic Current Distortion in Percent of $I_L$ | | | | | | |
|---|---|---|---|---|---|---|
| Individual Harmonic Order (Odd Harmonics) | | | | | | |
| $I_{sc}/I_L$ | <11 | 11≤*h*<17 | 17≤*h*<23 | 23≤*h*<35 | 35≤*h* | TDD |
| <20* | 4.0 | 2.0 | 1.5 | 0.6 | 0.3 | 5.0 |
| 20<50 | 7.0 | 3.5 | 2.5 | 1.0 | 0.5 | 8.0 |
| 50<100 | 10.0 | 4.5 | 4.0 | 1.5 | 0.7 | 12.0 |
| 100<1000 | 12.0 | 5.5 | 5.0 | 2.0 | 1.0 | 15.0 |
| >1000 | 15.0 | 7.0 | 6.0 | 2.5 | 1.4 | 20.0 |
| Even harmonics are limited to 25% of the odd harmonic limits above. | | | | | | |
| Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed. | | | | | | |
| * All power generation equipment is limited to these values of current distortion, regardless of actual $I_{sc}/I_L$. | | | | | | |
| where<br>$I_{sc}$ = maximum short-circuit current at PCC.<br>$I_L$ = maximum demand load current (fundamental frequency component) at PCC. | | | | | | |

**Table 10-2—Low-Voltage System Classification and Distortion Limits**

| | Special Applications* | General System | Dedicated System† |
|---|---|---|---|
| Notch Depth | 10% | 20% | 50% |
| THD (Voltage) | 3% | 5% | 10% |
| Notch Area ($A_N$)‡ | 16 400 | 22 800 | 36 500 |

NOTE — The value $A_N$ for other than 480 V systems should be multiplied by V/480

*Special applications include hospitals and airports.
†A dedicated system is exclusively dedicated to the converter load.
‡In volt-microseconds at rated voltage and current.


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