2013

El Paso Electric Company (EPE)

EPE Load Area Imports Limit Calculation (EPIC) Based on Updated Methodology (EPIC2) – Transformer Uprate Equation Report

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1.0 EXECUTIVE SUMMARY

In 2013, El Paso Electric Company (EPE) introduced an EPIC2 methodology, as detailed in a 2012 report, that included making adjustments to the EPE Load Area Import limit value (942 MW) in a specific (benchmark) case at which an EPE transmission element (autotransformer) reaches 100% of its emergency rating during a single-element outage with the Arroyo Phase-Shifting Transformer (PST) modeled as bypassed; this report details the specifics of the effect of raising the emergency rating of EPE's 345/115 kV autotransformers to 15% above their emergency rating (the transformer uprate).

In the 2012 EPIC2 work, the polynomial equations and logic for determining each adjustment were programmed into a spreadsheet. The end result of the calculation spreadsheet was that all adjustments were factored into adding, subtracting, or not changing a base value of 942 MW. Calculation spreadsheet values for a set of system conditions and inputs were verified so that the methodology, equation calculations, and logic could be verified against case results where EPIC values were determined under these conditions. EPIC calculated values based on EPIC1 and EPIC2 methodology were compared for EPIC2 cases in some samplings. In this report, a single polynomial and logic based equation that will yield a single number (this will be called the transformer adjustment) to be added to the original EPIC2 calculation to account for the transformer uprate.

When work began on EPIC2, the cases used did not model above a total Newman generation MW output of 637 MW. Therefore, as of this writing 0-637 MW is the relevant range for this methodology with the transformer uprate. Further work will continue on EPIC2.

2.0 INTRODUCTION

In these studies using EPIC2 methodology with the transformer uprate (as will be defined in the methodology section), EPE Load Area Import limit values were calculated for several EPE system conditions; note that, EPE local generation + EPE load area imports (EPI) = EPE load + EPE losses.

2.1 Objective

Determine a single equation that accounts for the transformer uprate that yields a single value to be added to the original EPIC2 calculation.

3.0 METHODOLOGY

Based on the same factors used in the original EPIC2 methodology:

1. Total Newman generation MW output and Westmesa-Arroyo 345 kV (EP) line MW flow,
2. Secondary Effects of Westmesa-Arroyo 345 kV (EP) line MW flow,
3. Copper generator MW output,
4. Total Luna Energy Facility (LEF) generation MW output,
5. Total Afton generation MW output (total Rio Grande generation MW output – indirectly with its effect on total Afton generation MW output effects), and
6. purchases or sales through the Artesia/Eddy HVDC tie (flowing on the Amrad-Artesia 345 kV line)

the transformer uprate was applied to a number of cases and new (increased) EPIC values were determined for these cases relative to the original EPIC2 methodology case (without the transformer uprate). From here, the effect of the aforementioned were programmed into a single polynomial and logic equation that used the required combination of the six factors according to the case and this equation will yield a single transformer uprate adjustment value to be added to the original (EPIC2 methodology) EPIC value to yield a EPIC final value.

A value of 942 MW EPI remained the base value.

The following inputs were used in the original EPIC2 value were used in the transformer uprate adjustment as well:

1. Total Newman generation MW output (range limited to 0-637 MW),
2. Westmesa-Arroyo 345 kV (EP) line MW flow (range limited to 0-390.7 NS with + sign convention being NS direction),
3. Copper generator MW output (range limited to 0-60 MW),
4. Total LEF generation MW output (range limited to 0-570 MW),
5. Total Afton generation MW output (range limited to 0-235 MW), and
6. Purchases or sales through the Artesia/Eddy HVDC tie (range limited to + 200 to – with – sign convention being a purchase by EPE).

Within a single Excel spreadsheet/file, EPE Operators could input values for the six EPIC2 variables previously mentioned plus total Rio Grande MW generation into one pre-programmed sheet to yield an estimate of the transformer uprate adjusted EPE Load Area Import limit value (EPIC based on EPIC2 methodology with the transformer uprate applied).

3.1 Case Development

In this study, powerflow cases modeling forecasted 2013 peak summer conditions (and variations of these cases) were developed for identifying El Paso Electric Company (EPE) electrical elements that may become overloaded (loaded above 115 % of their emergency rating) under a single-element outage; further cases continued to be developed as needed. The transformer uprate adjusted EPIC2 cases used assume all EPE local generation was available while examining the effects of varying the following factors:

1. Total Newman generation MW output and Westmesa-Arroyo 345 kV (EP) line MW flow,
2. Secondary Effects of Westmesa-Arroyo 345 kV (EP) line MW flow,
3. Copper generator MW output,
4. Total Luna Energy Facility (LEF) generation MW output,
5. Total Afton generation MW output (total Rio Grande generation MW output – indirectly with its effect on total Afton generation MW output effects), and
6. purchases or sales through the Artesia/Eddy HVDC tie (flowing on the Amrad-Artesia 345 kV line);

Because case variations involving different EPE load area load and loss levels were needed to examine the effect of the aforementioned variables, the effect of different load levels and power factors are implicit and inclusive to the transformer uprate adjusted EPIC2 methodology.

3.2 Development of Single Transformer Uprate Adjustment Value

The transformer uprate adjustment equation was developed by comparing the increase in EPI values uprate adjusted cases to the value for cases under the same conditions (but without the transformer uprate). From here, it was just a matter of finding the effect of each of the six factors in the original EPIC2 methodology beginning with 1 and 2 (see Section 3.1). Contributions from factors 3 to 6 built upon the effects of factors 1 and 2. The next step in development of the transformer uprate adjustment was to determine whether the effects of each of the six factors could be represented by a polynomial equation or a logic-based mathematical equation. After the effects of each of the six factors were determined as an equation, they were added to that they would yield one value to be added to the original EPIC2 methodology EPIC value to yield a final EPIC value.

3.3 Details of Six Parts of the Transformer Uprate Value (one for each factor)

3.3.1 Total Newman Generation MW Output and Westmesa-Arroyo 345 kV (EP) Line MW Flow Part (NEWEP Equation Part of Transformer Uprate Equation)

The total Newman generation MW output and Westmesa-Arroyo 345 kV (EP) Line MW Flow (NEWEP) equation part of the transformer uprate adjustment equation was worked in conjunction with cases examining the Secondary Westmesa-Arroyo (EP) 345 kV line MW flow (SEP) part and the effects of both the NEWEP and SEP were combined into one equation that was one part of the transformer adjustment equation.

3.3.2 NEWEP Adjustment Methodology

The NEWEP part examined the effect of varying total Newman generation MW output on the transformer uprate equation in conjunction with the EP line MW flow; the effect of varying total Newman generation MW output at same ideal PST MW schedule was key to this development.

3.3.3 Secondary Westmesa-Arroyo 345 kV (EP) Line MW Flow Adjustment (SEP Adjustment)

The Secondary Westmesa-Arroyo 345 kV line MW flow (SEP) part to of the transformer uprate adjustment equation was worked in conjunction with cases examining the NEWEP adjustment and the effects of both the NEWEP and SEP were combined into one equation that was one part of the transformer adjustment equation.

3.3.4 Copper Generator MW Output Adjustment (Copper Adjustment) Methodology

The Copper generator MW output adjustment (Copper adjustment) studies examined the effect of varying only Copper MW output on the transformer uprate equation.

3.3.5 Total Luna Energy Facility Generation MW Output Adjustment (LEF Adjustment) Methodology

The total LEF generation MW Output Adjustment (LEF Adjustment) studies examined the effect of varying only total LEF generation MW output on on the transformer uprate equation.

3.3.6 Total Afton Generation MW Output Adjustment (Afton Adjustment) Methodology

The total Afton generation MW Output Adjustment (Afton Adjustment) studies examined the effect of varying only total Afton generation MW output on the transformer uprate equation.

3.3.7 Artesia/Eddy HVDC Tie MW on Artesia-Amrad 345 kV Line Adjustment (Eddy Adjustment) Methodology

The Eddy Adjustment studies examined the effect of varying only Eddy MW on the transformer uprate equation.

4.0 APPLICATION

What follows is a description of the application of the results of this study into end products that will be used for programming and calculation purposes.

4.1 EPIC Spreadsheet Based on EPIC2 Methodology with Transformer Uprate Adjustment

The original polynomial equations and logic for determining each adjustment based on the original EPIC2 methodology were programmed into a spreadsheet together with the transformer uprate adjustment to yield a final EPIC value.

4.2 EPIC Calculation Spreadsheet Based on EPIC2 Methodology with Transformer Uprate Adjustment – Verification

The parts of the transformer uprate adjustment equation were verified as developed and readjusted as needed to yield satisfactory results within a final spreadsheet.

APPENDIX 1
FORMULAS

Combined NEWEP/SEP Part of Transformer Uprate Adjustment Equation

In formula that follows,

- A7 = total Newman generation MW output
- D7 = EP 345 kV line MW flow N-S

$$-5.782929706 \text{ x } (10)^{-10} \text{ x } (A7)^{4} + 1.396034444 \text{ x } (10)^{-6} \text{ x } (A7)^{3} - 9.321477414 \text{ x } (10)^{-4} \text{ x } (A7)^{2} + 9.917447516 \text{ x } (10)^{-2} \text{ x } (A7) + 135.3 + 1.040997302 \text{ x } (10)^{-6} \text{ x } (D7)^{3} - 8.999070125 \text{ x } (10)^{-4} \text{ x } (D7)^{2} + 2.711756583 \text{ x } (10)^{-1} \text{ x } (D7) - 29.36653498$$

Copper Part of Transformer Uprate Adjustment Equation

In formula that follows,

- B7 = Copper Generator MW output

$$+ 1.666666667 \text{ x } (10)^{-3} \text{ x } (B7)^{2} - 1.166666667 \text{ x } (10)^{-1} \text{ x } (B7) - 1.776356839 \text{ x } (10)^{-15}$$

Total Luna Energy Facility Generation MW Output Part of Transformer Uprate Adjustment Equation

In formula that follows,

- A7 = total Newman Generation MW output
- E7 = total LEF Generation MW output

$$+\text{IF}(\text{AND}(E7>=0,E7<=142.5),(7.01754386 \text{ x } (10)^{-3} \text{ x } E7) \text{ x } (-5.152899414 \text{ x } (10)^{-10} \text{ x } (A7)^{4}+6.181765659 \text{ x } (10)^{-7} \text{ x } (A7)^{3}-1.810469847 \text{ x } (10)^{-4} \text{ x } (A7)^{2}+2.052097841 \text{ x } (10)^{-2} \text{ x } (A7)+4.6),\text{IF}(\text{AND}(E7>142.5,E7<=285),((-7.01754386 \text{ x } (10)^{-3} \text{ x } E7+2) \text{ x } (-5.152899414 \text{ x } (10)^{-10} \text{ x } (A7)^{4}+6.181765659 \text{ x } (10)^{-7} \text{ x } (A7)^{3}-1.810469847 \text{ x } (10)^{-4} \text{ x } (A7)^{2}+2.052097841 \text{ x } (10)^{-2} \text{ x } (A7)+4.6))+((6.823119957 \text{ x } (10)^{-10} \text{ x } (A7)^{4}-1.228900319 \text{ x } (10)^{-6} \text{ x } (A7)^{3}+6.601642994 \text{ x } (10)^{-4} \text{ x } (A7)^{2}-7.586501141 \text{ x } (10)^{-2} \text{ x } (A7)+6.6) \text{ x } (7.01754386 \text{ x } (10)^{-3} \text{ x } E7-1)),\text{IF}(\text{AND}(E7>285,E7<=570),((6.823119957 \text{ x } (10)^{-10} \text{ x } (A7)\text{\textasciicircum}4-1.228900319 \text{ x } (10)^{-6} \text{ x } (A7)^{3}+6.601642994 \text{ x } (10)^{-4} \text{ x } (A7)\text{\textasciicircum}2-7.586501141 \text{ x } (10)^{-2} \text{ x } (A7)+6.6) \text{ x } (-3.50877193 \text{ x } (10)^{-3} \text{ x } E7+2))+((3.361015913 \text{ x } (10)^{-9} \text{ x } (A7)^{4}-5.025039596 \text{ x } (10)^{-6} \text{ x } (A7)^{3}+2.321802085 \text{ x } (10)^{-3} \text{ x } (A7)^{2}-2.845606047 \text{ x } (10)^{-1} \text{ x } (A7)+9.3) \text{ x } (3.50877193 \text{ x } (10)^{-3} \text{ x } E7-1)),0)))$$

Artesia/Eddy MW Flow Part of Transformer Uprate Adjustment Equation

Sign Convention:

- = Artesia/Eddy to Amrad
+ = Amrad to Artesia/Eddy

In formula that follows,

- A7 = total Newman Generation MW output
- G7 = Artesia/Eddy MW Flow

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+IF(AND(G7>=0,G7<=30),0,IF(AND(G7>30,G7<=50),((-3.566104616*10^-
9*A7^4+4.810127785*10^-6*A7^3-2.154165691*10^-3*A7^2+3.569863353*10^-1*A7-
1.3)*(0.02*G7)),IF(AND(G7>50,G7<=100),(((-3.566104616*10^-9*A7^4+4.810127785*10^-
6*A7^3-2.154165691*10^-3*A7^2+3.569863353*10^-1*A7-1.3)*(-
0.02*G7+2))+((2.577679414*10^-9*A7^4-3.365912984*10^-6*A7^3+1.249233052*10^-
3*A7^2-7.757799611*10^-2*A7-1.6)*(0.02*G7-1))),IF(AND(G7>100,G7<=150),(((-
2.324367724*10^-10*A7^4+1.024470937*10^-7*A7^3-6.528524944*10^-
5*A7^2+8.358099604*10^-2*A7-4.9)*(0.02*G7-2))+((2.577679414*10^-9*A7^4-
3.365912984*10^-6*A7^3+1.249233052*10^-3*A7^2-7.757799611*10^-2*A7-1.6)*(-
0.02*G7+3))),IF(AND(G7>150,G7<=200),(((-2.324367724*10^-10*A7^4+1.024470937*10^-
7*A7^3-6.528524944*10^-5*A7^2+8.358099604*10^-2*A7-4.9)*(-0.02*G7+4))+((-
2.401146588*10^-9*A7^4+2.555227082*10^-6*A7^3-9.251948841*10^-
4*A7^2+1.990558835*10^-1*A7-7.6)*(0.02*G7-3))),0)))))+IF(AND(G7<=0,G7>=-
30),0,IF(AND(G7<-30,G7>=-50),((1.191458883*10^-9*A7^4 + 6.09056064*10^-7*A7^3 -
1.294472768*10^-3*A7^2 + 3.597477999*10^-1*A7 - 9.2)*(-0.02*G7)),IF(AND(G7<-
50,G7>=-100),(((1.191458883*10^-9*A7^4 + 6.09056064*10^-7*A7^3 - 1.294472768*10^-
3*A7^2 + 3.597477999*10^-1*A7 - 9.2)*(0.02*G7 + 2))+((4.401293351*10^-9*A7^4 -
2.17250567*10^-6*A7^3 - 4.195680246*10^-4*A7^2 + 2.176915467*10^-1*A7 - 10.1)*(-
0.02*G7 - 1))),IF(AND(G7<-100,G7>=-150),(((4.401293351*10^-9*A7^4 - 2.17250567*10^-
6*A7^3 - 4.195680246*10^-4*A7^2 + 2.176915467*10^-1*A7 - 10.1)*(0.02*G7 + 3))+((-
5.865222294*10^-9*A7^4 + 1.108584701*10^-5*A7^3 - 5.506039205*10^-3*A7^2 +
8.455530456*10^-1*A7 - 21.7)*(-0.02*G7 - 2))),IF(AND(G7<-150,G7>=-200),(((-
5.865222294*10^-9*A7^4 + 1.108584701*10^-5*A7^3 - 5.506039205*10^-3*A7^2 +
8.455530456*10^-1*A7 - 21.7)*(0.02*G7 + 4))+((-1.431985243*10^-8*A7^4 +
2.125383086*10^-5*A7^3 - 8.999754347*10^-3*A7^2 + 1.240757412*A7 - 33)*(-0.02*G7 -
3))),0)))))+IF(AND(A7<=92,A7>=0),(-2.755907391*10^-21*D7^10 + 4.997906706*10^-
18*D7^9 - 3.777099345*10^-15*D7^8 + 1.544410344*10^-12*D7^7 - 3.718427057*10^-
10*D7^6 + 5.388998828*10^-8*D7^5 - 4.622653403*10^-6*D7^4 + 2.221151324*10^-4*D7^3
- 5.290446662*10^-3*D7^2 + 3.281599626*10^-2*D7 - 3.928877306*10^-1)*( -
1.086956522*10^-2*A7 + 1),0)
```

This formula will be left in Excel format to prevent errors.

<u>Total Afton Generation MW Output Part of Transformer Uprate Adjustment Equation</u>

In formulas that follow,

- A7 = total Newman Generation MW output
- F7 = total Afton Generation MW output

$$+(\mathrm{IF}(\mathrm{AND}(F7>=0,F7<=141),((0.007092199 \text{ x } F7+1.110223025 \text{ x } (10)^{-16}) \text{ x } (-7.633462188 \text{ x } (10)^{-10} \text{ x } (A7)^{4}+7.928199913 \text{ x } (10)^{-7} \text{ x } (A7)^{3}-1.622107517 \text{ x } (10)^{-4} \text{ x } (A7)^{2}+1.315519537 \text{ x } (10)^{-2} \text{ x } (A7)+2.2)),\mathrm{IF}(\mathrm{AND}(F7>141,F7<=235),(2.556549065 \text{ x } (10)^{-9} \text{ x } (A7)^{4} - 3.215997151 \text{ x } (10)^{-6} \text{ x } (A7)^{3} + 1.204561945 \text{ x } (10)^{-3} \text{ x } (A7)^{2} - 8.124242704 \text{ x } (10)^{-2} \text{ x } (A7) + 6.2) \text{ x } (1.098901098 \text{ x } (10)^{-2} \text{ x } F7 - 1.582417581),0)))$$

Transformer Uprate Adjustment Equation (Excel Format)

= (-5.782929706*10^-10*A7^4 + 1.396034444*10^-6*A7^3 - 9.321477414*10^-4*A7^2 +
9.917447516*10^-2*A7 + 135.3 + 1.040997302*10^-6*D7^3 - 8.999070125*10^-4*D7^2 +
2.711756583*10^-1*D7 - 29.36653498 + 1.666666667*10^-3*B7^2 - 1.166666667*10^-1*B7 -
1.776356839*10^-15)+(IF(AND(F7>=0,F7<=141),((0.007092199*F7+1.110223025*10^-16)*(-
7.633462188*10^-10*A7^4+7.928199913*10^-7*A7^3-1.622107517*10^-
4*A7^2+1.315519537*10^-2*A7+2.2)),IF(AND(F7>141,F7<=235),(2.556549065*10^-9*A7^4
- 3.215997151*10^-6*A7^3 + 1.204561945*10^-3*A7^2 - 8.124242704*10^-2*A7 +
6.2)*(1.098901098*10^-2*F7 -
1.582417581),0)))+IF(AND(E7>=0,E7<=142.5),(7.01754386*10^-3*E7)*(-5.152899414*10^-
10*A7^4+6.181765659*10^-7*A7^3-1.810469847*10^-4*A7^2+2.052097841*10^-
2*A7+4.6),IF(AND(E7>142.5,E7<=285),((-7.01754386*10^-3*E7+2)*
(-5.152899414*10^-10*A7^4+6.181765659*10^-7*A7^3-1.810469847*10^-
4*A7^2+2.052097841*10^-2*A7+4.6))+((6.823119957*10^-10*A7^4-1.228900319*10^-
6*A7^3+6.601642994*10^-4*A7^2-7.586501141*10^-2*A7+6.6)*(7.01754386*10^-3*E7-
1)),IF(AND(E7>285,E7<=570),((6.823119957*10^-10*A7^4-1.228900319*10^-
6*A7^3+6.601642994*10^-4*A7^2-7.586501141*10^-2*A7+6.6)*(-3.50877193*10^-3*E7+2
))+((3.361015913*10^-9*A7^4-5.025039596*10^-6*A7^3+2.321802085*10^-3*A7^2-
2.845606047*10^-1*A7+9.3)*(3.50877193*10^-3*E7-
1)),0)))+IF(AND(G7>=0,G7<=30),0,IF(AND(G7>30,G7<=50),((-3.566104616*10^-
9*A7^4+4.810127785*10^-6*A7^3-2.154165691*10^-3*A7^2+3.569863353*10^-1*A7-
1.3)*(0.02*G7)),IF(AND(G7>50,G7<=100),(((-3.566104616*10^-9*A7^4+4.810127785*10^-
6*A7^3-2.154165691*10^-3*A7^2+3.569863353*10^-1*A7-1.3)*(-
0.02*G7+2))+((2.577679414*10^-9*A7^4-3.365912984*10^-6*A7^3+1.249233052*10^-
3*A7^2-7.757799611*10^-2*A7-1.6)*(0.02*G7-1))),IF(AND(G7>100,G7<=150),(((-
2.324367724*10^-10*A7^4+1.024470937*10^-7*A7^3-6.528524944*10^-
5*A7^2+8.358099604*10^-2*A7-4.9)*(0.02*G7-2))+((2.577679414*10^-9*A7^4-
3.365912984*10^-6*A7^3+1.249233052*10^-3*A7^2-7.757799611*10^-2*A7-1.6)*(-
0.02*G7+3))),IF(AND(G7>150,G7<=200),(((-2.324367724*10^-10*A7^4+1.024470937*10^-
7*A7^3-6.528524944*10^-5*A7^2+8.358099604*10^-2*A7-4.9)*(-0.02*G7+4))+((-
2.401146588*10^-9*A7^4+2.555227082*10^-6*A7^3-9.251948841*10^-
4*A7^2+1.990558835*10^-1*A7-7.6)*(0.02*G7-3))),0)))))+IF(AND(G7<=0,G7>=-
30),0,IF(AND(G7<-30,G7>=-50),((1.191458883*10^-9*A7^4 + 6.09056064*10^-7*A7^3 -
1.294472768*10^-3*A7^2 + 3.597477999*10^-1*A7 - 9.2)*(-0.02*G7)),IF(AND(G7<-
50,G7>=-100),(((1.191458883*10^-9*A7^4 + 6.09056064*10^-7*A7^3 - 1.294472768*10^-
3*A7^2 + 3.597477999*10^-1*A7 - 9.2)*(0.02*G7 + 2))+((4.401293351*10^-9*A7^4 -
2.17250567*10^-6*A7^3 - 4.195680246*10^-4*A7^2 + 2.176915467*10^-1*A7 - 10.1)*(-
0.02*G7 - 1))),IF(AND(G7<-100,G7>=-150),(((4.401293351*10^-9*A7^4 - 2.17250567*10^-
6*A7^3 - 4.195680246*10^-4*A7^2 + 2.176915467*10^-1*A7 - 10.1)*(0.02*G7 + 3))+((-
5.865222294*10^-9*A7^4 + 1.108584701*10^-5*A7^3 - 5.506039205*10^-3*A7^2 +
8.455530456*10^-1*A7 - 21.7)*(-0.02*G7 - 2))),IF(AND(G7<-150,G7>=-200),(((-
5.865222294*10^-9*A7^4 + 1.108584701*10^-5*A7^3 - 5.506039205*10^-3*A7^2 +
8.455530456*10^-1*A7 - 21.7)*(0.02*G7 + 4))+((-1.431985243*10^-8*A7^4 +
2.125383086*10^-5*A7^3 - 8.999754347*10^-3*A7^2 + 1.240757412*A7 - 33)*(-0.02*G7 -
3))),0)))))+IF(AND(A7<=92,A7>=0),(-2.755907391*10^-21*D7^10 + 4.997906706*10^-
18*D7^9 - 3.777099345*10^-15*D7^8 + 1.544410344*10^-12*D7^7 - 3.718427057*10^-
10*D7^6 + 5.388998828*10^-8*D7^5 - 4.622653403*10^-6*D7^4 + 2.221151324*10^-4*D7^3
- 5.290446662*10^-3*D7^2 + 3.281599626*10^-2*D7 - 3.928877306*10^-1)*(-
1.086956522*10^-2*A7 + 1),0)