Capacity Expansion Alternatives For the Trumbull / Shelton Area

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Background

The United Illuminating Company (UI) is planning for additional load growth in the Trumbull/Shelton area. The Old Town Substation supplies electric power to approximately one half of the Town of Trumbull and the northernmost section of the City of Bridgeport. The Trap Falls Substation supplies electric power to the easternmost section of the Town of Trumbull, the southern half of the Town of Shelton, and the northernmost section of the Town of Stratford. UI analysis shows that a single contingency that results in the unavailability of a substation transformer, at either substation, could require load shedding by the summer of 2005 unless corrective action is taken. UI has prepared a need statement and has conducted preliminary engineering and economic evaluation for four alternatives:

1. Build a new 115 kV/13.8 kV substation in the Town of Trumbull, Connecticut. The new substation will consist of two 13.8 kV buses fed by two 24/32/40 MVA transformers, with a firm capacity of approximately 58 MVA. The new substation will be designed and operated with the bus-tie breaker in the normally open position. It will initially be configured with four 13.8 kV feeder breaker positions.
2. Transfer load from Trap Falls and Old Town to other substations through distribution load transfers (new feeders and distribution duct lines required).
3. Install a single 40 MVA Power Delivery System (PDS) at proposed Trumbull substation site
4. Build a new substation at a different location

Engineering and economic analysis, performed by UI, showed that building a new substation is the preferred solution. UI retained EPRI Solutions, Inc. to assist in the review of solutions identified by UI and to assist UI in the identification and evaluation of other possible alternatives. This report presents the results of that effort.

Executive Summary

EPRI Solutions, Inc reviewed the expected load growth for the Trap Falls and Old Town substation area and then evaluated different solutions for dealing with the growth. EPRI Solutions, Inc. evaluated the economics of the different solutions as well as their impact on system reliability and quality. The following is a summary of the findings:

1. With all equipment in service, UI has adequate capacity to meet anticipated maximum demand over the next five years, even under extreme summer conditions. However, an outage of critical equipment serving the Trumbull/Shelton area during extreme summer temperatures will result in overloads requiring load shedding. Such actions would negatively affect UI system reliability performance.

2. Weather normalization of the loads indicates that if the temperatures in the summer of 2004 had been like those in 2001, the failure of a single 115 kV to 13.8 kV substation transformer at either Old Town or Trap Falls, would have resulted in overloads in the remaining transformer. That would have required some temporary load shedding. It is estimated that a transformer failure and subsequent load shedding operation could add approximately 1.7 minutes to the System Average Interruption Duration Index (SAIDI) (1500 customers * 6 hours of load shedding / 315,000 customers). UI is required by law to maintain SAIDI and the System Average Interruption Frequency Index (SAIFI) at 1998 levels.

3. The summer peak loading on the Old Town substation is currently significantly above the value that can cause voltage collapse. In order to avoid this voltage collapse issue the Old Town bus-tie-breaker is operated in the open position any time the substation load exceeds 65 MVA (20 MVA below substation firm rating). A transformer failure could impact SAIDI and SAIFI since at this loading level it will take more than 5 minutes for systematically moving the customers fed from the affected transformer to the other transformer.

4. A transmission line outage while operating with the open bus-tie breaker will result in lower power quality because nearly all load equipment without Uninterrupted Power Supply (UPS) backup will trip offline during the resulting interruption that could be as much as 20 seconds. However, the bus-tie open configuration will result in higher power quality for the more common type of events (voltage sags due to individual 13.8 kV feeder faults) because approximately half of the customers supplied from that substation are more isolated from the distribution faults.

5. The Trap Falls substation has a transient voltage stability loading limit equal to the substation firm rating so there is currently no inherent need to open the bus-tie breaker. In any event, the bus tie-breaker at Trap Falls must remain closed because of the dual feeds to Sikorsky (opening the bus-tie may cause circulating currents within the Sikorsky facility).

6. There were initially four alternatives proposed by UI to deal with the load growth and increased risk of load shedding. EPRI Solutions, Inc. expanded this list and evaluated the following ten different alternatives (first 4 provided by UI):
    a. Build Trumbull Substation
    b. Transfer load from Old Town and Trap Falls to other substations
    c. Install 40 MVA modular substation (PDS)
    d. Build substation at alternate site
    e. Replace transformers at Old Town and Trap Falls with larger units
    f. Feeder enhancement / distribution automation
    g. Distributed Generation
    h. Conservation and Load Management
    i. Complementary combinations of above listed options

   j. Do nothing (shed required amount of load if simultaneous occurrence of extreme summer temperatures and unexpected equipment outages occur).

7. UI is operating under certain constraints and has established reliability planning criteria (N-1) that influence the optimum solution selection process. The key constraints are:
   a. The UI service territory currently has a large number of unoccupied commercial properties that could cause unusually rapid increases in system loads. It is estimated that in the Trumbull/Shelton area about 25% of the existing commercial property is vacant. (Appendix C contains a partial listing of load additions that could materialize up through 2009.)
   b. UI is required to provide the reliability of service that is the same or better than the reliability levels that existed during 1998. This has been interpreted as the current four-year average reliability should be the same or better than the four-year average ending in 1998.
   c. The loading on the 1710/1730 transmission lines has significantly impacted the maintenance and operability of these lines and any additional loading on these lines would exacerbate the problem. A major 345 kV transmission line project (Middletown-Norwalk) is expected to be added to the UI service territory in southwestern Connecticut by the year 2009 and would not provide the needed relief of these lines until this time frame.
   d. UI has historically designed distribution substations with two identical transformers (typically feeding two buses with the bus tie closed). The total loading on the substation has been limited to the "firm rating" of the substation which is generally the maximum amount of load that one of the transformers could carry for approximately 24 hours (one load cycle). This arrangement eliminates the need to drop load in the event of a transformer failure (i.e. mobile substation brought in within 24 hours).
   e. Existing area substation and distribution infrastructure configuration excludes application of Distributed Generation as an immediately available substation capacity solution in the affected area.
   f. UI's recent substation designs have tended toward smaller transformers due to voltage support, fault duty, transportability and contingency plan concerns (e.g., Allings Crossing, Indian Well, Mill River, Broadway, and Congress). This new design philosophy allows for possibly more DG to be interconnected to at these new substations' distribution system.
   g. UI has not yet started any pilot projects utilizing "distribution automation" and lacks infrastructure for such systems.
   h. UI only owns a portion of the transmission lines in its service territory, which results in UI paying "transmission line usage charges." (Reference Figure 3)

8. The Trumbull substation option will immediately improve power quality (reduce the number of voltage sags) for customers fed from the Old Town and Trap Falls substations because fewer customers will be fed from those substations (i.e. fewer feeders or shorter feeder lengths). Any immediate improvement in the reliability indices SAIDI (System Average Interruption Duration Index) or SAIFI (System Average Interruption Frequency Index) will be limited to the previously mentioned values if one of the Old Town or Trap Falls transformers failed during high loading conditions and/or to the extent that some feeder shortening can be accomplished with the initial four feeder configuration. However, once the new substation is fully developed (10 feeder positions) distribution circuits can be reconfigured and improvements in SAIDI and SAIFI can be expected along with a reduction in feeder losses as well as improved voltage performance.

9. The Trumbull substation option has the following salient features:
   a. Consistent with UI's historical approach for maintaining N-1 reliability planning criteria.

b. Provides capacity margin for the Trumbull/Shelton area until sometime after the year 2015.
c. Provides capacity margin for both Old Town and Trap Falls substations until sometime after the year 2015
d. Reduces the risk of voltage collapse at Old Town by reducing the amount of time that the bus-tie breaker is operated in the open position.
e. Is in line with UI's philosophy of smaller substation transformers.
f. Reduces "transmission line usage charges" that UI must pay by $220,000 per year (with the initial amount of load transfer to Trumbull substation).
g. Physical location is advantageous from a transmission interconnection point of view, allowing for the least initial cost for distribution infrastructure to provide load reliably for both Old Town and Trap Falls substations.
h. Provides needed capacity at the lowest infrastructure cost.
i. Capital Intensive (approximately $13.4 Million).
j. The earliest a new Trumbull substation could become operational is prior to the summer peak of 2007.
k. By design, will provide connectivity for future Distributed Generation capacity.

Conclusions and Recommendations

1. From the initial list of ten alternatives, building the Trumbull substation is the best long-term solution consistent with the constraints and circumstances mentioned above.

2. The weather normalized load forecast indicates that the Old Town and Trap Falls substations are both presently at risk of overload should summer temperatures approach those experienced in 1999 and 2001. The potential for 5-10% more load if now-vacant office space becomes occupied exacerbates this risk. Therefore, a prudent response would be to proceed with construction of the Trumbull substation on the earliest practical schedule. Based on the constraints described above, the goal would be to have the substation operational before the summer peak of 2007.

Geographical Overview and Observations

Figure 1 shows the basic geographical area of interest. The distance between Old Town and Trap Falls substations is approximately six miles. The planned location for the Trumbull substation is also indicated (circled). UI plans to energize all or part of the four 13.8 kV feeders shown in Figure 1 from the new substation. The feeders scheduled to be transferred to the new substation are Old Town 2627 and 2620 and Trap Falls 3545 and 3547.

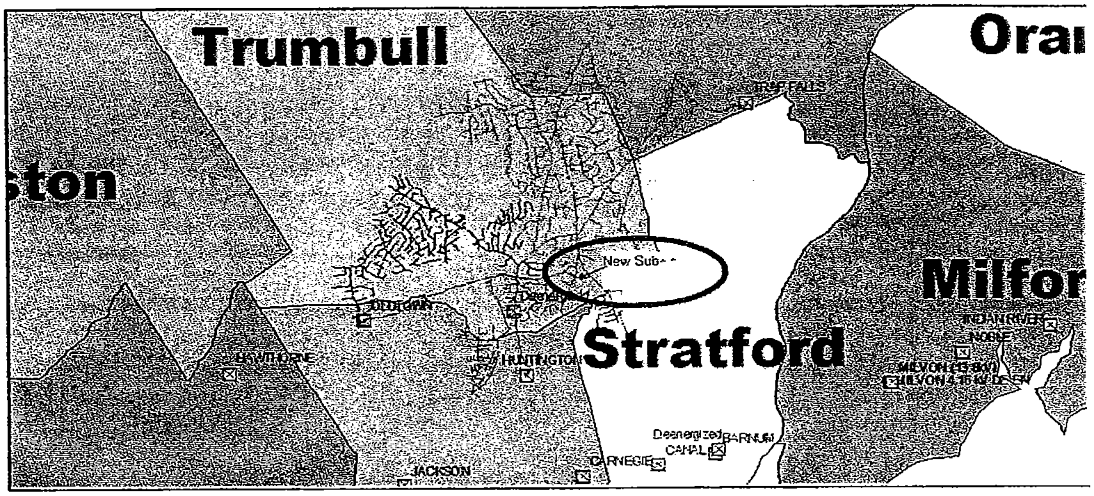

Figure 1 - Trumbull Junction Geographical Location – Selected Feeders Shown

The non-coincident peak loading for these four feeders is summarized in the following table.

Table 1- Non-Coincident Peak Loading for Four Selected Feeders

	UI - Peak Feeder Loading					Base kV (L-L)=		14.20
			Amps			Base kV (L-N) =		8.20
sub	Feeder	Date	Phase A	Phase B	Phase C	% Current Imbalance	Power Factor	Total KVA at (14.2 kV)
Old Town	2620	Jun-02	284	322	299	7	0.99	7,420
Old Town	2627	Sep-01	418	453	406	6	0.99	10,469
Trap Falls	3545	Jul-02	276	286	285	2	0.99	6,944
Trap Falls	3547	Jun-03	388	405	343	9	0.99	9,313
							Total=	34,146

Figure 2 shows all of the existing feeders out of both Old Town and Trap Falls. The locations for Old Town, Trap Falls and the new substation are circled. Typically, a distribution substation should be located near the geographic center of the distribution planning area it serves to maintain a short average feeder length. Visually, it would appear that a site located about 2.5 to 3 miles north or northwest of the selected site might have inherently better distribution feeder characteristics.

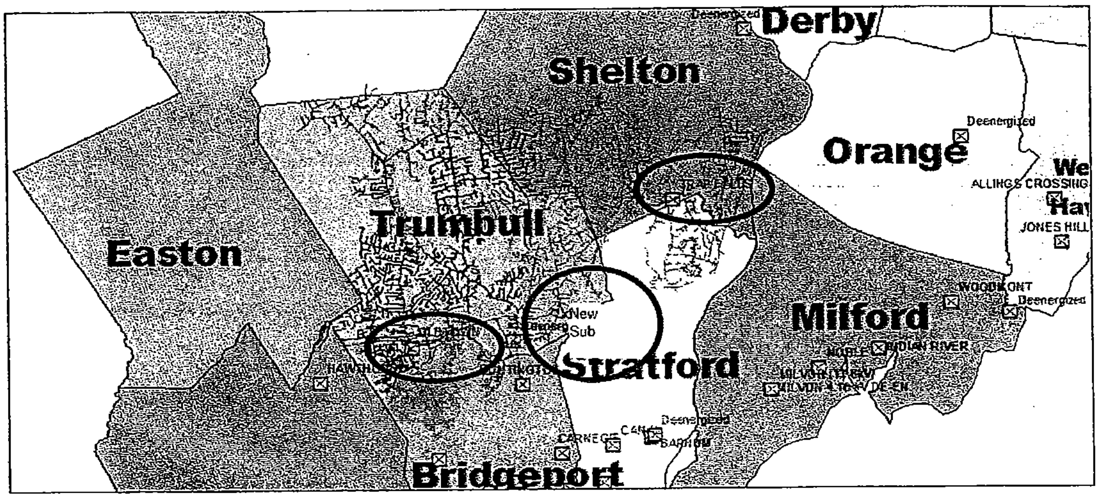

Figure 2 - Old Town and Trap Falls Geography - All Feeders

Substation location is always a compromise between transmission and distribution considerations. While the selected location for the new substation may not be ideal from a distribution point of view, it is very well located with respect to the location of the existing transmission system (Figure 3).

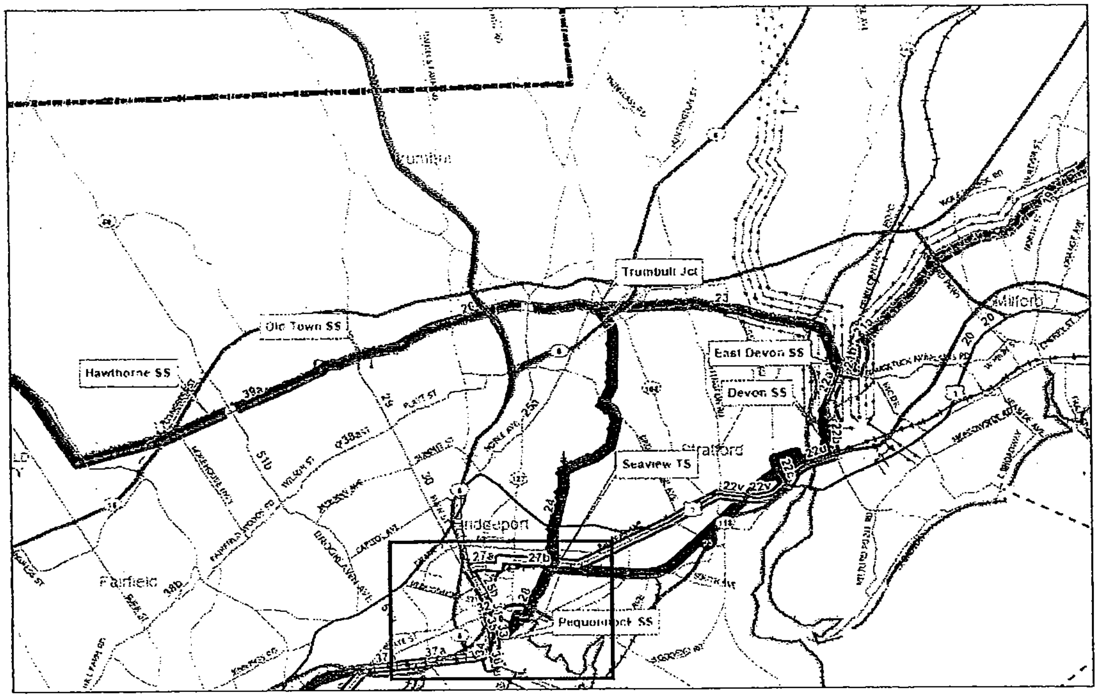

Figure 3 - Trumbull Junction Geography -Transmission Lines and Highways

LEGEND

- Limited Access Highway
- Highway
- Roads
- Railroad
- Pipeline
- UI 115-kV Transmission Lines
- UI 115-kV Underground Transmission Lines
- CL&P 115-kV Transmission Lines
- CL&P Underground 115-kV Transmission Lines
- CL&P 345-kV Transmission Lines
- Undersea Transmission Lines

Figure 3 shows that Trumbull Junction is the termination point for the "UI owned" 115 kV transmission lines (Lines 1710 and 1730). See Reference 6. Both Old Town and Trap Falls (not shown) are fed from Connecticut Light & Power (CL&P) 115 kV transmission lines. Relocating 35 MW of load such that it is directly fed from "UI owned" transmission lines at Trumbull Junction will result in an estimated savings to UI of $220K per year ($63K for every 10 MW) due to a reduction in CL&P transmission line usage charges. Relocating 35 MW of load from Old Town and Trap Falls is not expected to have a significant impact on UI transmission line losses.

Reference 10 suggests that the 115 kV tap line to the proposed Trumbull substation site is going to be "direct" (i.e. no appreciable length). The costs associated with building 115 kV tap lines to some of the nine potential locations is estimated to be between 3 and 4 million dollars per mile. This high cost structure for building 115 kV tap lines severely limits substation site location options.

The substation single lines for Old Town and Trap Falls substations are shown in Appendix A as are the pertinent parts of the 115 kV transmission system.

Substation Design Criteria

With regard to major distribution substations, UI has historically followed what is known as an "N-1" design criterion. This means that UI customers would not experience an outage (other than perhaps a momentary outage) for serious single contingency events such as the failure of a 115 kV-13.8 kV transformer. This design criterion requires that the total load being fed from the substation not exceed the "firm rating" of the substation. Additionally, the requirement that acceptable voltage be maintained at the secondary bus at the firm rating of the substation has tended UI toward installing smaller size transformers.

The UI "firm rating" of multiple transformer substations with interconnected secondaries is equal to the peak of the maximum daily load cycle which can be carried by this substation upon the first contingency loss of one substation transformer. The emergency loading capability of substation transformers is commonly the determinant of the firm capacity of these substations.

The loading levels on the Old Town and Trap Falls substations have risen to the point that the substations firm ratings are either currently exceeded or will be exceeded by the Summer of 2005. Allowing the load to go beyond the substations firm rating is a violation of the basic design guide because it could require load to be shed during a contingency event (depending upon loading at the time of the contingency).

In general, violations of historical design criteria should not be allowed because UI is required by law not to reduce system reliability below the July 1, 1998 values. The impact of any allowed violations on SAIDI and SAIFI would have to be quantified and quantifiable offsetting improvements would have to be made in order not to risk violating the 1998 values.

In addition to not violating the firm rating, the total system load should, in general, not exceed that which can cause "voltage collapse" upon loss of one of the transformers. Voltage collapse can sometimes occur during the loss of one transformer because the remaining transformer immediately picks up the entire substation load. This does not allow time for the load tap changers to adjust to the new loading requirements. The voltage collapse issue can be avoided by operating the substation with the bus-tie open and then picking up any dropped load in a manner that gives the load tap changer a chance to re-adjust.

The following table, Table 2, summarizes both the firm rating and voltage collapse (stability) ratings in MVA for the Old Town and Trap Falls substations as well as some of the other substations in the general vicinity (Reference 3 and 4)

Table 2 – Substation Firm Ratings (MVA) and Voltage Collapse Limits

	Old Town	Trap Falls	Hawthorne	Barnum	Indian Wells
Substation Firm Rating	85.5	76.6	99.6	54.1 (switchgear limitation)	74.5
Voltage Stability	65.0	76.0 (ref 3)	65.0	NA	NA
Transformer Nameplate Rating	36/48/60	30/40/50	42/56/70	42/56/70	24/32/40

The "firm" substation ratings shown above were developed by UI utilizing the PT Load software program. These results look reasonable and are consistent with accepting a small amount of loss of life, up to 5% per event.

The voltage collapse limits shown above were obtained from Reference 3 and Reference 11. They were derived based on a post-transient voltage criteria of 12.42 kV (90% of 13.8 kV). The large difference between the Old Town firm rating and the voltage stability limit, as compared to the differential at Trap Falls, suggests that today's basic operation of the Old Town substation is probably not consistent with a "bus-tie" closed philosophy. The impedance of the Old Town substation transformers is about 14% which is about 2% higher than the transformers at Trap Falls.

Substation Loading

Existing Substation Loading

The hourly loading data (total) on the Old Town substation for the years 1998 through 2004 is graphically displayed in Figures 4 – 9. It should be noted that the hourly loading levels are the net substation peak load with all conservation and load management programs in place at the time.

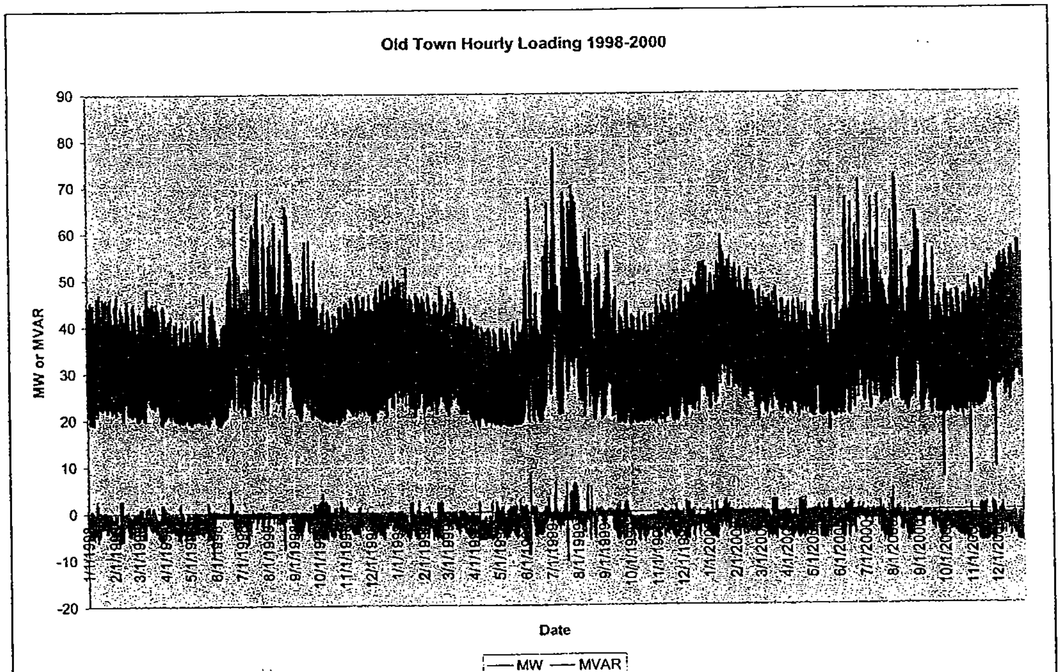

Figure 4 - Old Town Substation Hourly MW and MVAR Loading (1998-2000)

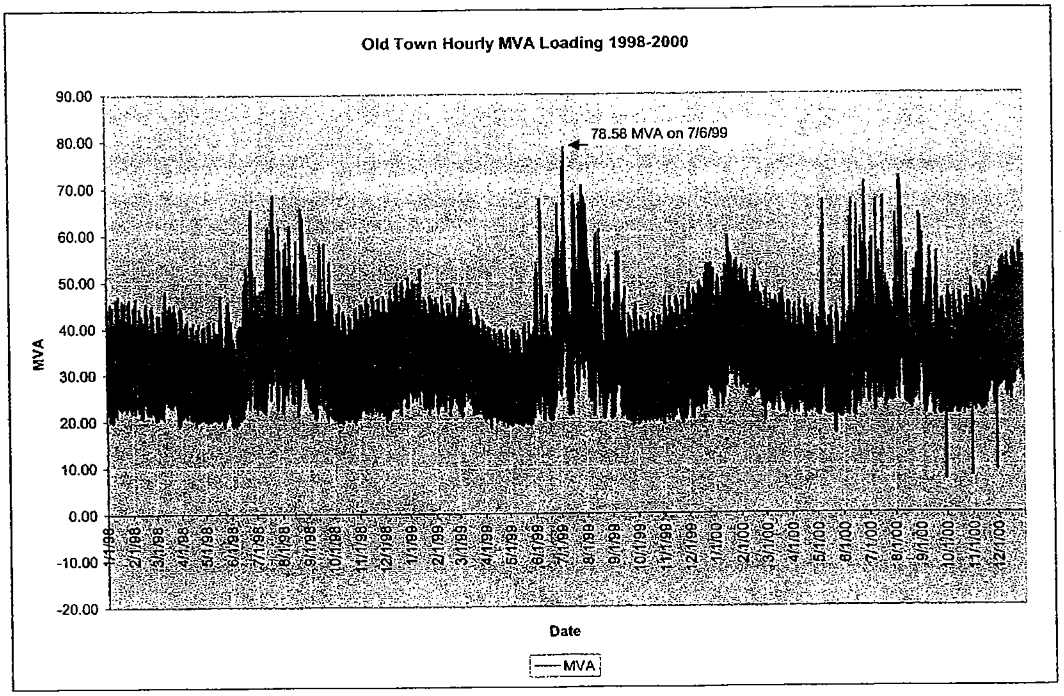

Figure 5 - Old Town Substation Hourly MVA Loading (1998-2000)

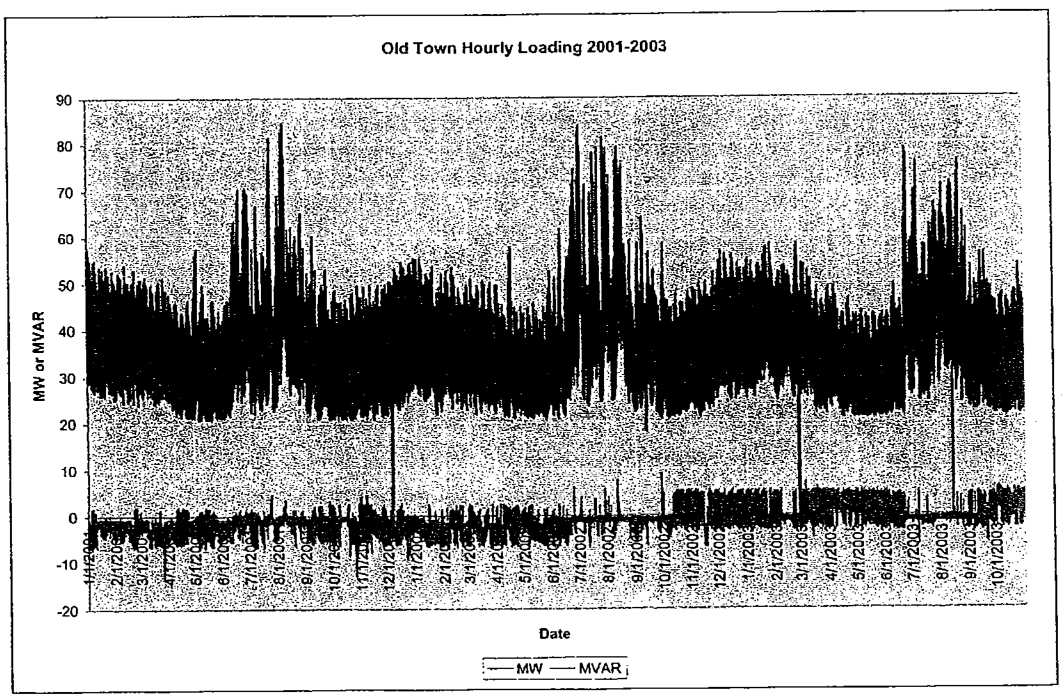

Figure 6 - Old Town Substation Hourly MW and MVAR Loading (2001-2003)

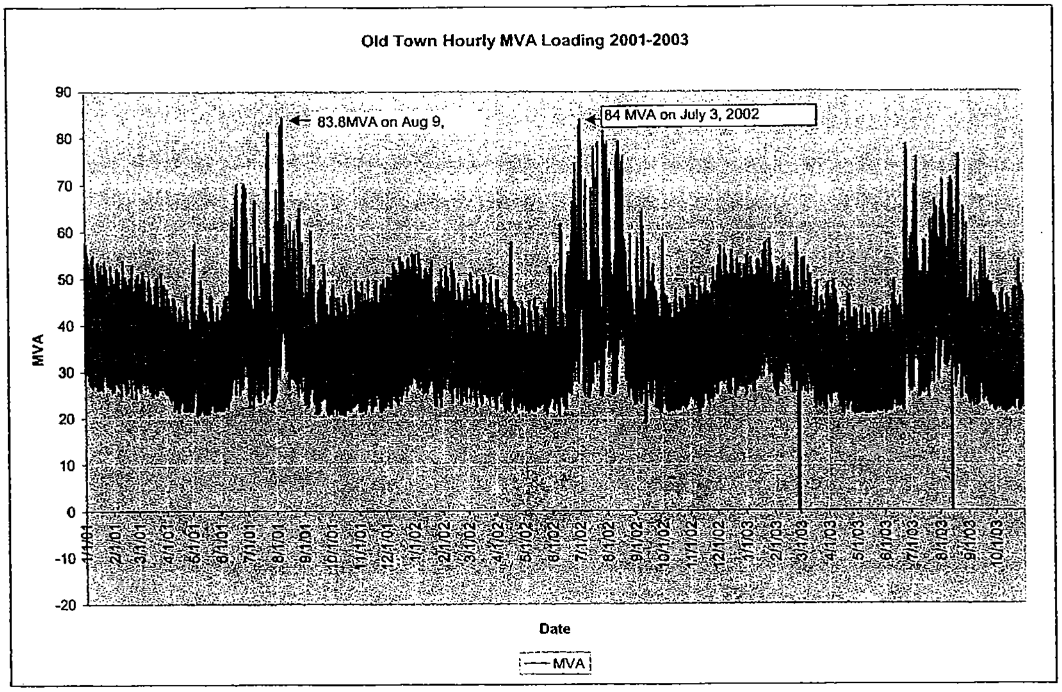

Figure 7 - Old Town Substation Hourly MVA Loading (2001-2003)

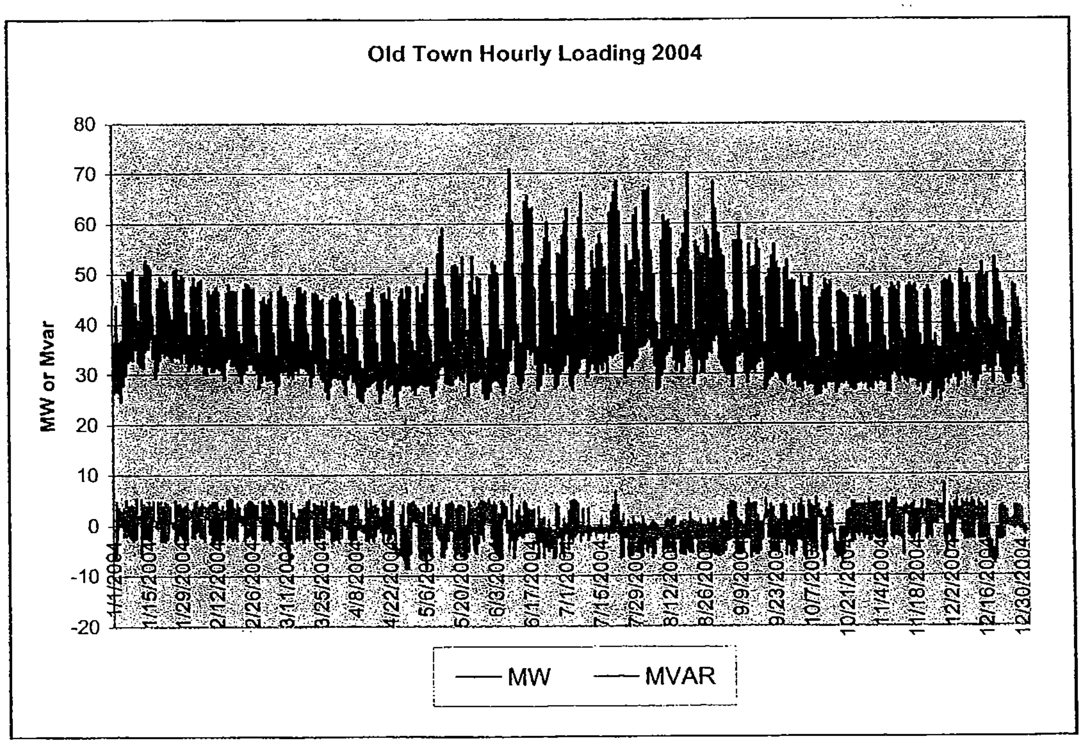

Figure 8. Old Town Substation Hourly MW and MVAR Loading (2004)

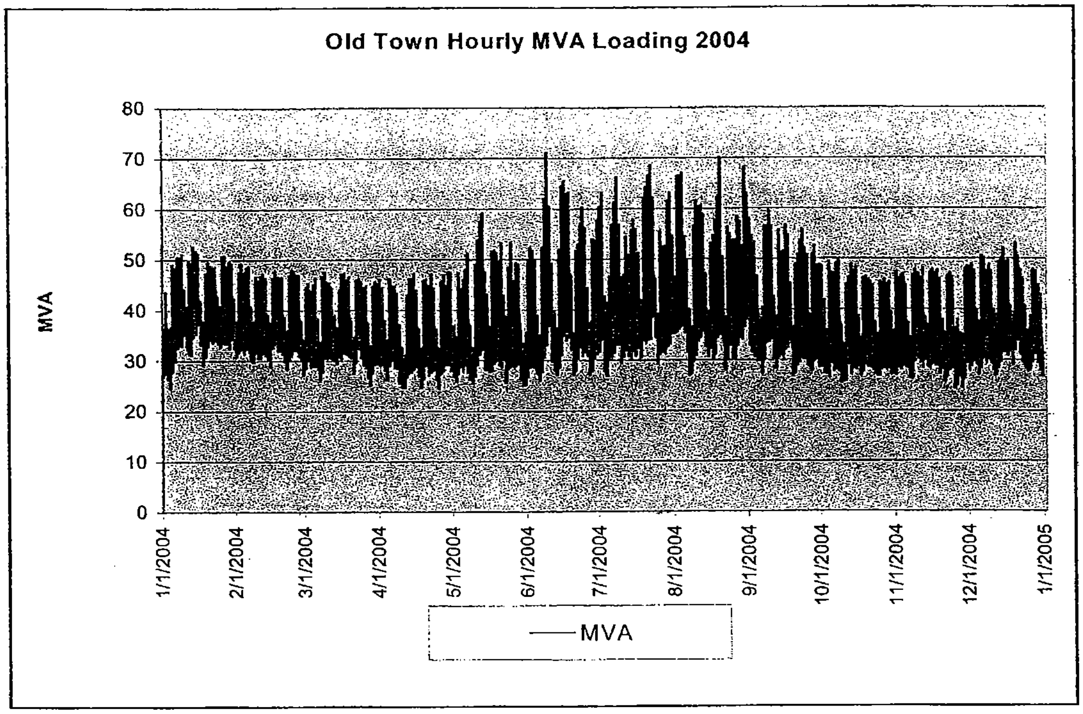

Figure 9. Old Town Substation Hourly MVA Loading (2004)

The preceding figures clearly demonstrate the summer peaking nature of the Old Town substation and they also indicate that the peak load may vary as much as 10 - 20 MVA from one summer day to the next. The above figures also demonstrate that the firm rating of 85.5 MVA has not yet been violated, although the loading in 1999 and 2001 came quite close. There are typically three days each summer in which the load reaches a distinct peak.

The peak loading day that occurred at the Old Town substation for the years 1998 to 2004 occurred on July 3, 2002. The daily MVA load cycle for that day (and +/- 12 hours) is shown in the following figure.

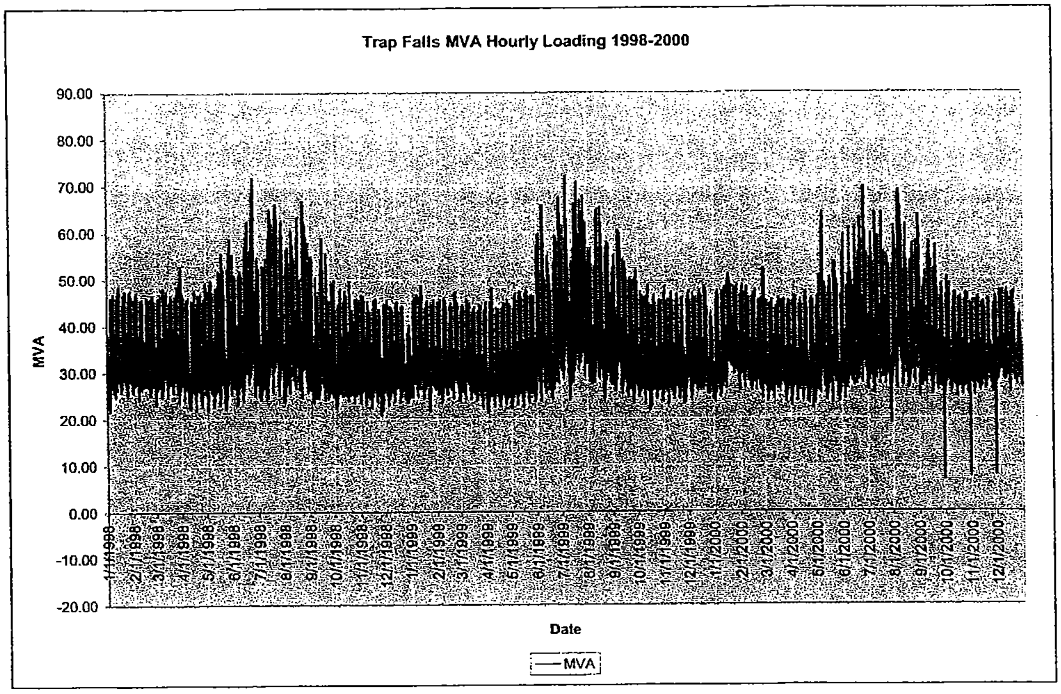

Figure 12 - Trap Falls MVA Hourly Loading 1998-2000

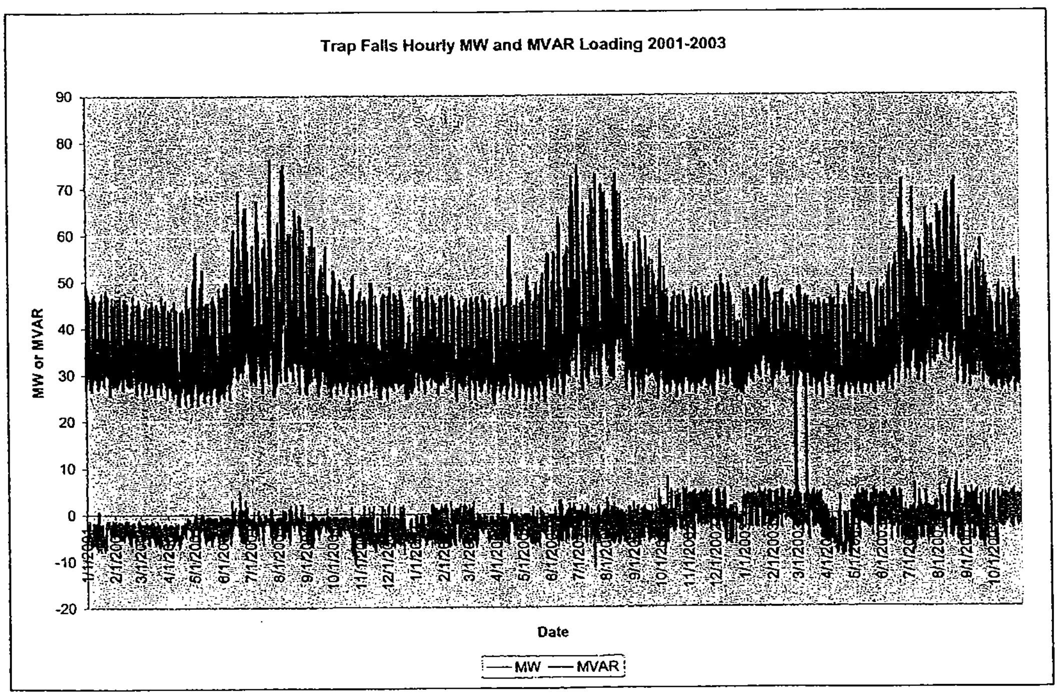

Figure 13 - Trap Falls Hourly MW and MVAR Loading 2001-2003

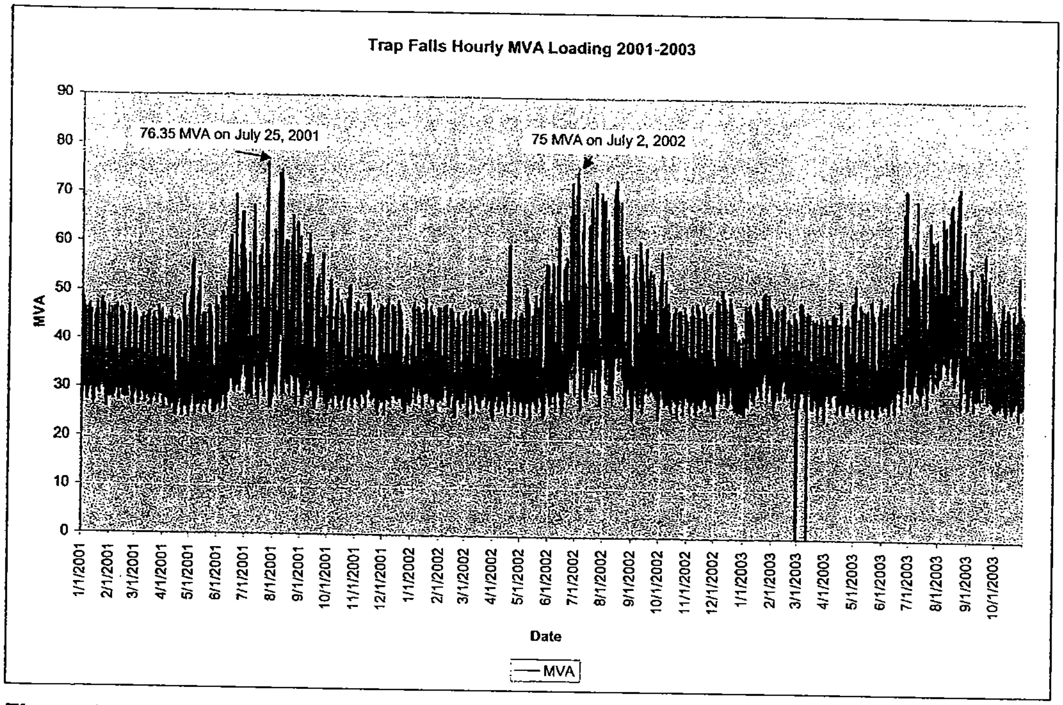

Figure 14 - Trap Falls Hourly MVA Loading 2001-2003

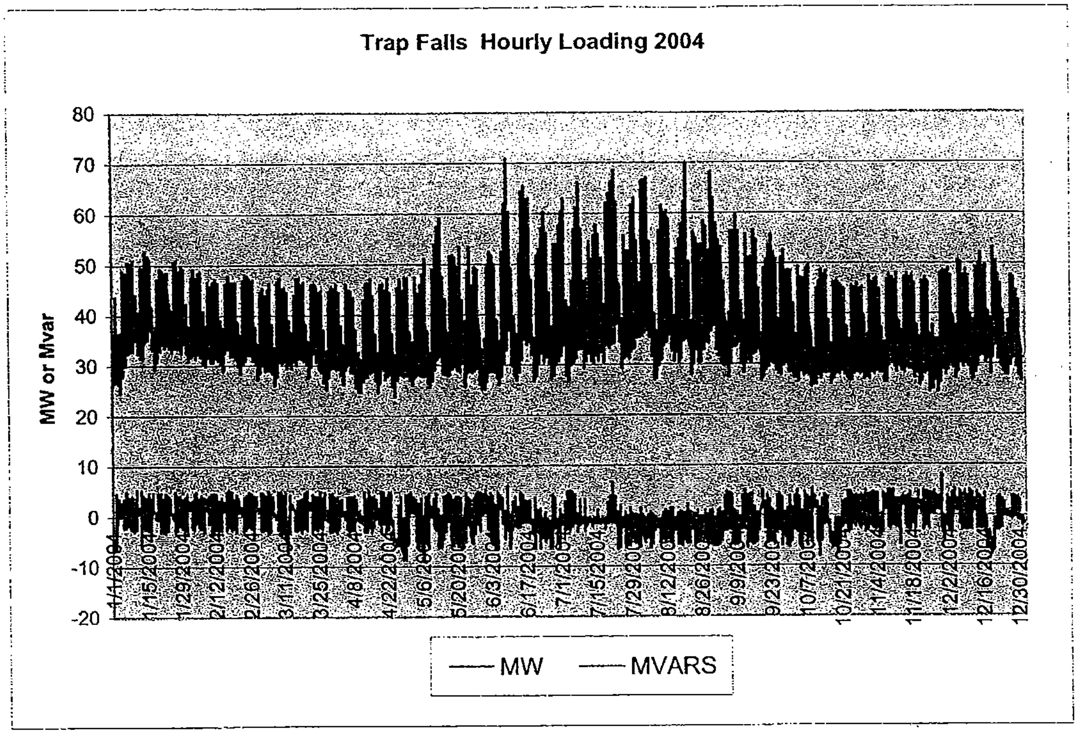

Figure 15. Trap Falls Hourly Loading (2004)

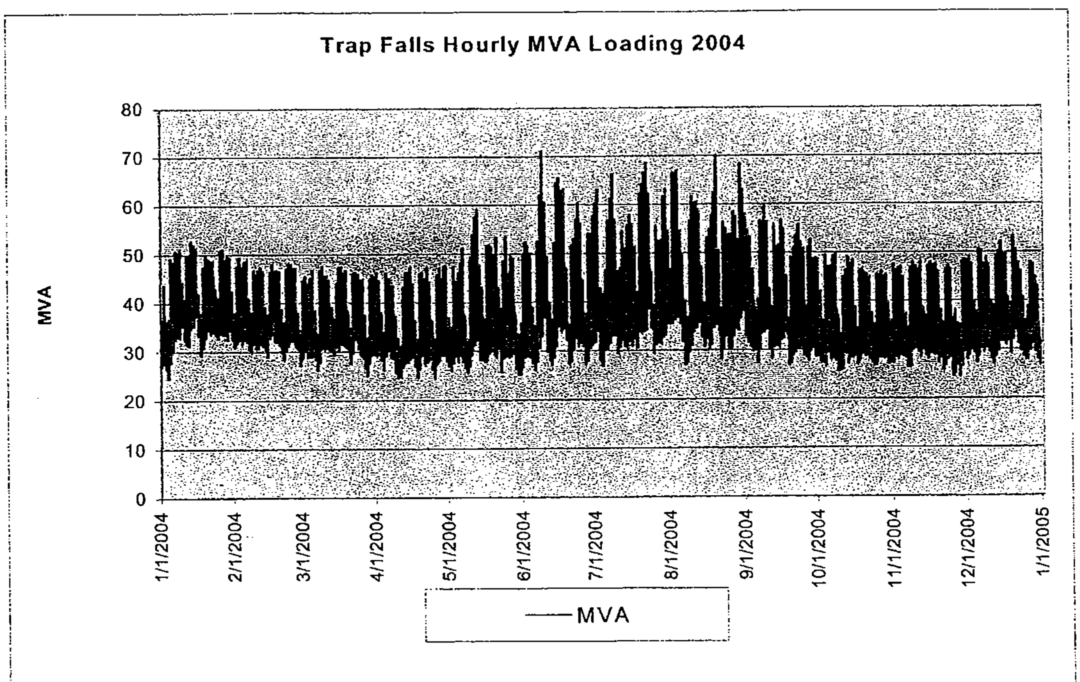

Figure 16. Trap Falls Hourly MVA Loading (2004)

The Trap Falls load shape characteristics are very similar to that previously described for Old Town. The firm rating of 76.6 MVA was nearly reached on July 25, 2001 but subsequent years have resulted in slightly lower peaks. The reduced peak is a combination of milder weather and/or some feeder load transfer to adjacent substations.

The daily MVA load cycle for July 2, 2002 is shown below in Figure 17. The reduction in load as the loading cycle proceeds after the peak is similar to the Old Town loading cycle, although the percentage reduction is not as great. The comments made for Figure 10 apply here as well.

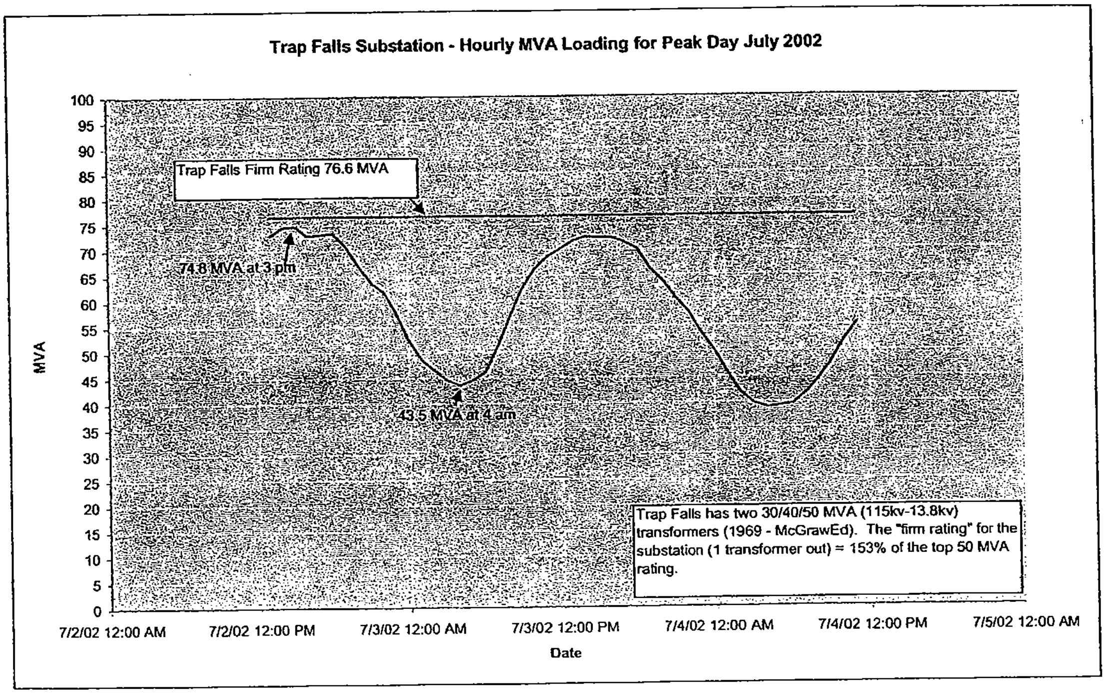

Figure 17 - Trap Falls Hourly MVA Loading - Peak day July 2002

<u>Build Substation At Alternate Site</u>
Reference 10 evaluated nine different sites in detail for the new substation. The high cost of building 115 kV tap transmission lines ($3M – $4M per mile) eliminated all sites with the potential to be superior to the selected site. The nine sites that were evaluated in detail in Reference 10 were all located south of Merritt Parkway even though the majority of the load and expected growth is centered about 3 miles north of the Parkway (Figures 2 & 3). The high cost of 115 kV tap lines eliminates this option.

<u>Replace Transformers at Old Town and Trap Falls with Larger Units</u>
Reference 13 quantified the economics associated with replacing the transformers at Old Town and Trap Falls with new 42/56/70 MVA transformers. The cost reported in Reference 13 totaled $6.8M but did not include the cost of upgrading the distribution delivery system, which was subsequently estimated to be $1.5M bringing the total cost to approximately $8.3M. The cost to upgrade the transformers is comparable to, or slightly greater than, the cost of building the new Trumbull substation ($13.4 Million) after the savings associated with the reduction in transmission line charges ($220K/year) are credited to Trumbull substation option. The high cost of uprating the transformers eliminates the practicality of this option since the new substation would provide additional enhancements to both the availability and power quality that would not be obtained by simply uprating the transformers at Old Town and Trap Falls. Additionally, larger transformers in UI substation designs would lead to serious operating issues due to voltage and equipment rating considerations that prevent their use.

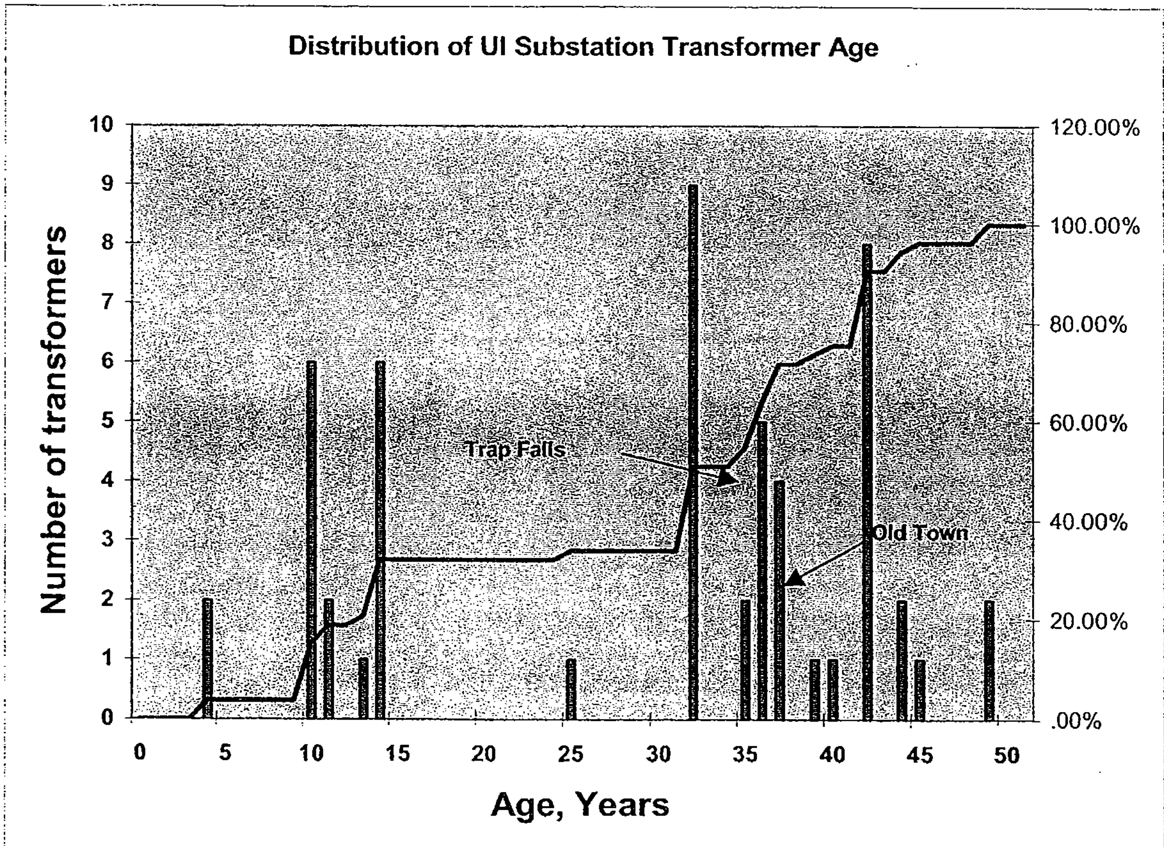

Figure 22 - Major Substation Transformer Age Profile

The age of the existing transformers at Old Town and Trap Falls, relative to the rest of the UI substation transformers, is shown in Figure 22. The Old Town and Trap Falls transformers are over 35 years old, which is approaching the 40 year design life. Half of the UI transformers are 35 years old, or older. It is however generally accepted that the "true age" of a transformer is more influenced by its thermal history then by its chronological age. The historical UI substation design philosophy has resulted in relatively light loads (25%-75% of max rating) on the individual transformers as can be seen by comparing the transformer ratings in Table 2 with the substation loading plots provided in this report. It is reasonable to assume that these transformers could last for more than the 40 year design life. However, EPRI Solutions does not recommend exceeding 50 years, a recommendation that is consistent with the practice of many other utilities. None of the 115 kV to 13.8 kV substation transformers are older than this, although two will reach this age next year. Therefore, assuming that there have been no loading anomalies in the histories of the transformers at Trap Falls and Old Town, approximately 10 years of life remains before their replacement would be recommended. A more accurate estimate of the remaining life of the transformers can be obtained by performing a furfural analysis of the oil and reviewing a detailed loading history along with any significant thermal events.

Feeder Enhancement / Distribution Automation

Feeder enhancement refers to combinations of distribution automation, feeder length reduction and feeder reliability improvement programs. The fundamental problem with this as a stand-alone option is that it does not add any transformer capacity. Because additional transformer capacity is critical to avoiding the potential need for load shedding this option will be eliminated as a "stand-alone" option but will be discussed later in the "Complementary combinations" section.

Distributed Generation (DG)

DG could potentially be utilized to displace substation loading in some applications. Several technical issues preclude the use of a DG solution in this specific application:

1. Existing short circuit levels at UI substations are high and the available fault interrupting capabilities of UI substation equipment is at or near their limits.
2. The addition of any sizable DG would contribute additional fault current which could cause equipment, such as circuit breakers and structural bracing, to be overdutied, possibly causing catastrophic damage to the equipment and risking employee safety.
3. Although DG may improve local capacity, it does not improve the reliability of the distribution system, as the same overall exposure would exist on the distribution circuit.

In order to interconnect significant amount of DG in this area a new substation must be built first.

Conservation and Load Management (C&LM)

UI has offered conservation and load management programs to its customers for over a decade. The cumulative effects of the programs are reflected in the load data that is used in developing the base case for the load forecast. The forecasted C&LM activity is included in identified customer load increases, system sales growth projections and Economic Development Major Project Forecast. UI has long been a proponent of the benefits of C&LM activities and has developed a full complement of C&LM programs as part of Connecticut's restructured electric markets. These programs have delivered load reductions from Commercial and Industrial customers served by these two substations alone. These are reflected in the historic substation loading levels, and C&LM programs will not defer the need for a new substation any longer.

Complementary combinations

The two concepts that complement each other in this situation are "Feeder Enhancement" and "Additional Transformer Capacity". The main potential leverage in this area requires the acceptance of distribution automation. UI is not currently prepared to fully exploit the benefits of distribution automation so options like "Install 40MVA PDS" have been eliminated at this time. The final solution "Building Trumbull Substation" will however incorporate the "feeder length reduction" concept once the substation has been fully expanded.

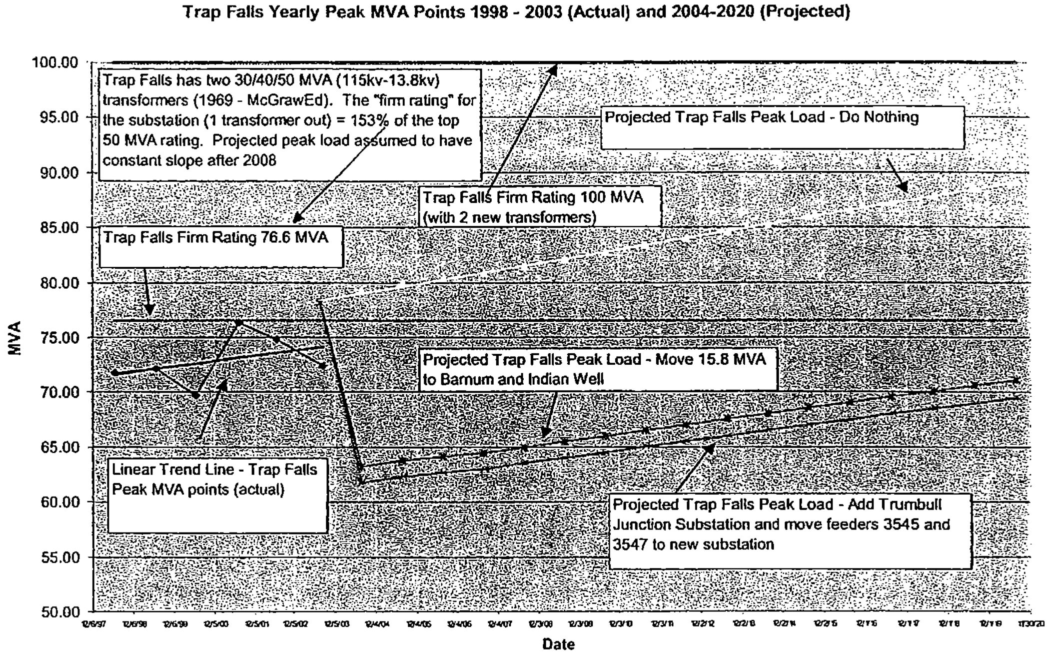

Figure 24 - Evaluating Solution Alternatives Impact on Old Town

The green lines in the above two figures indicate that there is a 5 – 10 % margin between the projected load at Old Town and Trap Falls and their corresponding "Firm ratings" even in the year 2020 provided that the new substation is built and the designated amount of load is relocated to the new substation. As previously stated the construction of the new substation does not resolve the contingency transient voltage stability limit at Old Town, which is 65 MVA.

The new substation at Trumbull Junction is scheduled to have a firm rating of 58 MVA and the initial peak load being transferred to this new substation is about 33 MVA. Assuming a load growth of 2% compounded for 15 years results in a load of 45 MVA being present in the year 2020. Therefore the new Trumbull substation will be operating within its firm rating beyond the year 2020.

References:

1. "TSS - 2.11 Emergency Loading Capability of Sub Power Transformers ", UI, 2/27/91.
2. "UI Preliminary Analysis for Trumbull Substation", UI.
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4. Spreadsheet file: "ui txf ratings 08 06 04.xls".
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6. Municipal Consultation Filing, Connecticut Siting Council Docket 272
7. The Reliability and Performance of United Illuminating Transmission & Distribution System for 2004, dated April 8, 2005.
8. "Power Transformer Design Enhancements Made to Increase Operational Life", David J. Woodcock and Jeffrey C. Wright, P.E., Weidmann Technical Services Inc.
9. Distribution System Planning Report, AGL, 2002, dated December 2002.
10. "United Illuminating, Trumbull Substation Site Selection Study".
11. Update to Post Transient Voltage Study.
12. 5 Yr Plan substation 2002 non-coincident peak loads.xls.
13. "Old Town and Trap Falls Substation Uprating Study Report", Black and Veatch, dated April 27, 2004.

Appendix A – UI System Diagrams

This appendix contains the following figures:

UI Service Territory
Old Town Substation Single Line (Each Transformer = 115-13.8 kV 36/48/60 MVA
Trap Falls Substation Single Line (Each Transformer = 115-13.8 kV, 30/40/50 MVA
Old Town 13.8 kV Feeders
Trap Falls 13.8 kV Feeders
Old Town Transmission Single Line
Trap Falls Transmission Single Line

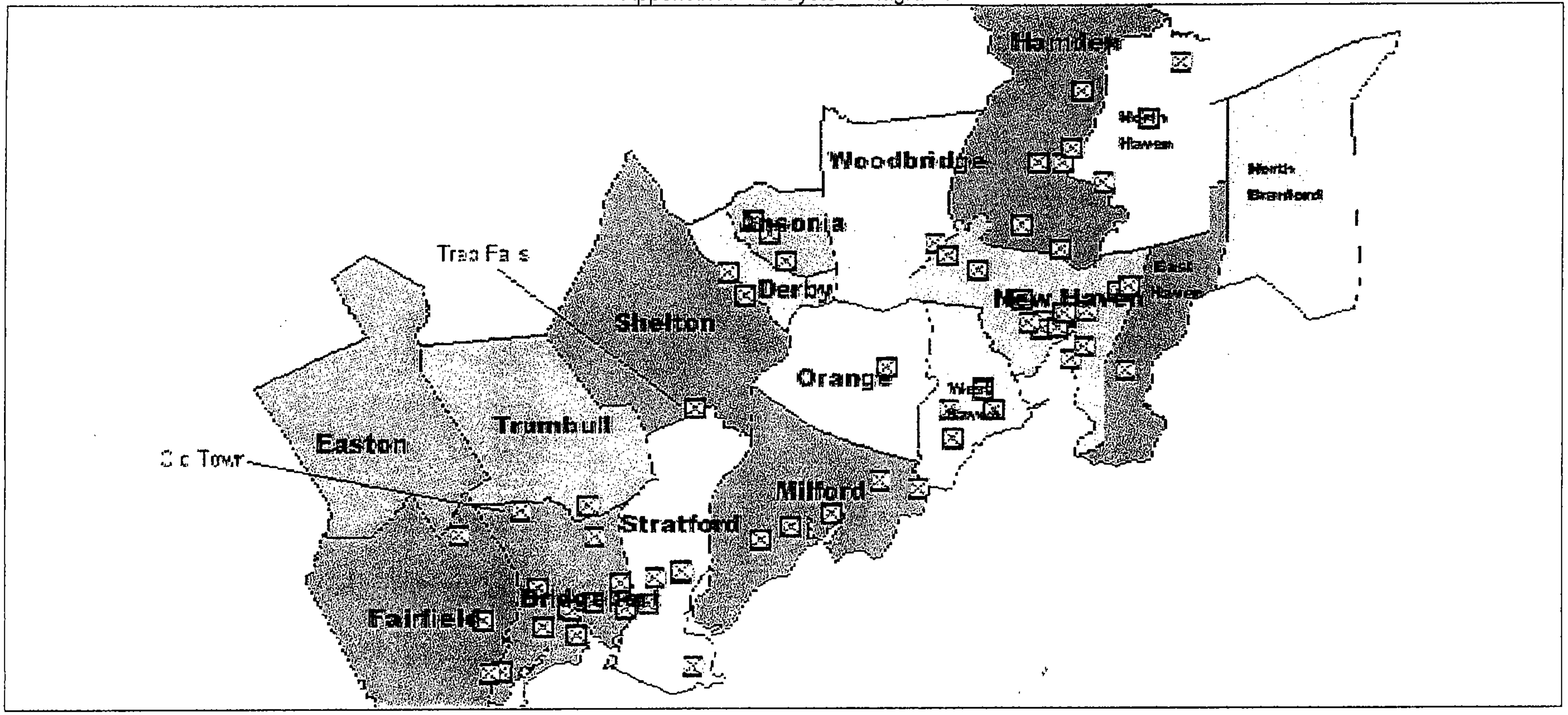

Figure 25 - UI Service Territory

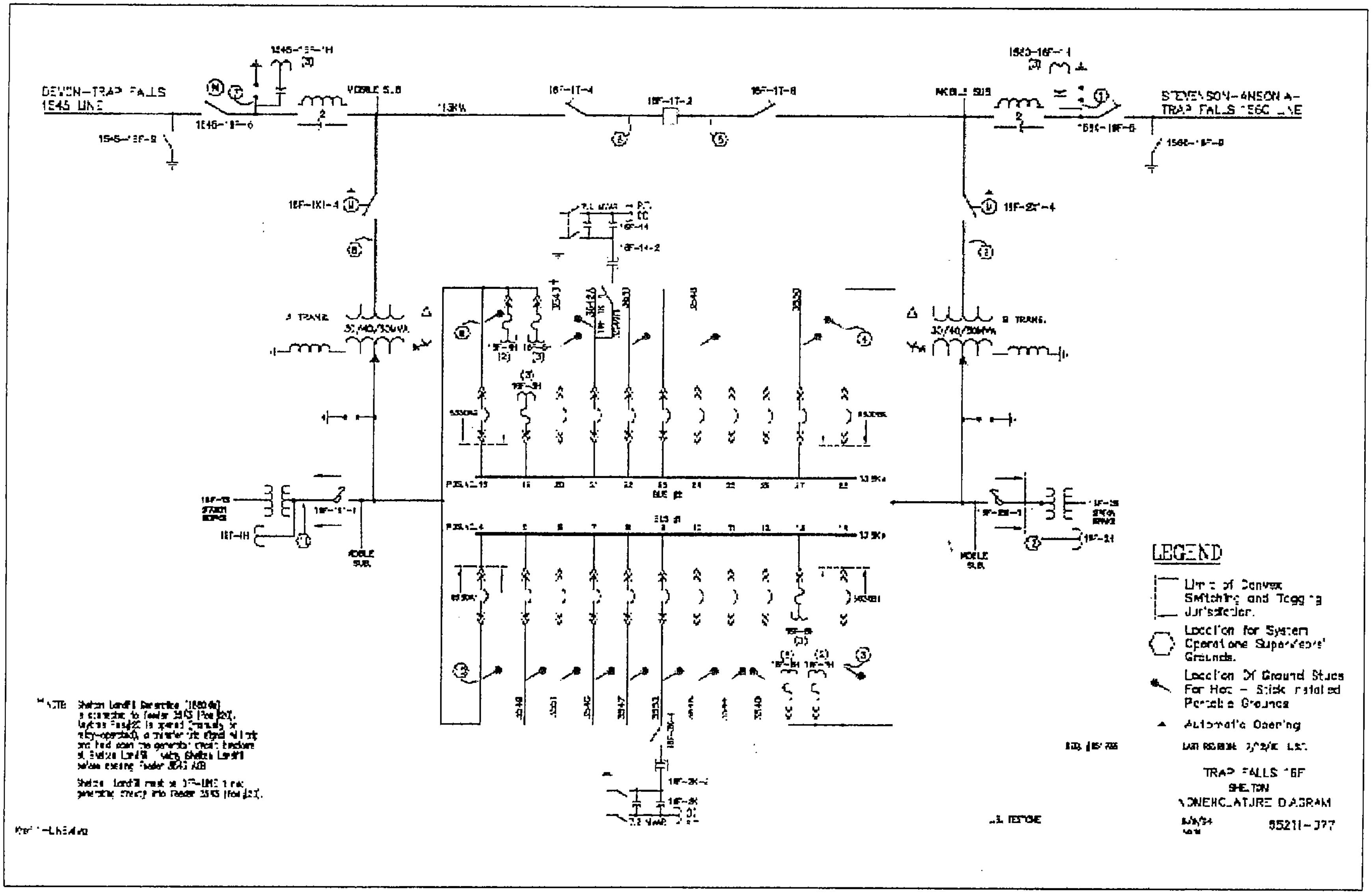

Figure 27 - Trap Falls Substation Single Line (Each Transformer = 115-13.8 kV, 30/40/50 MVA)

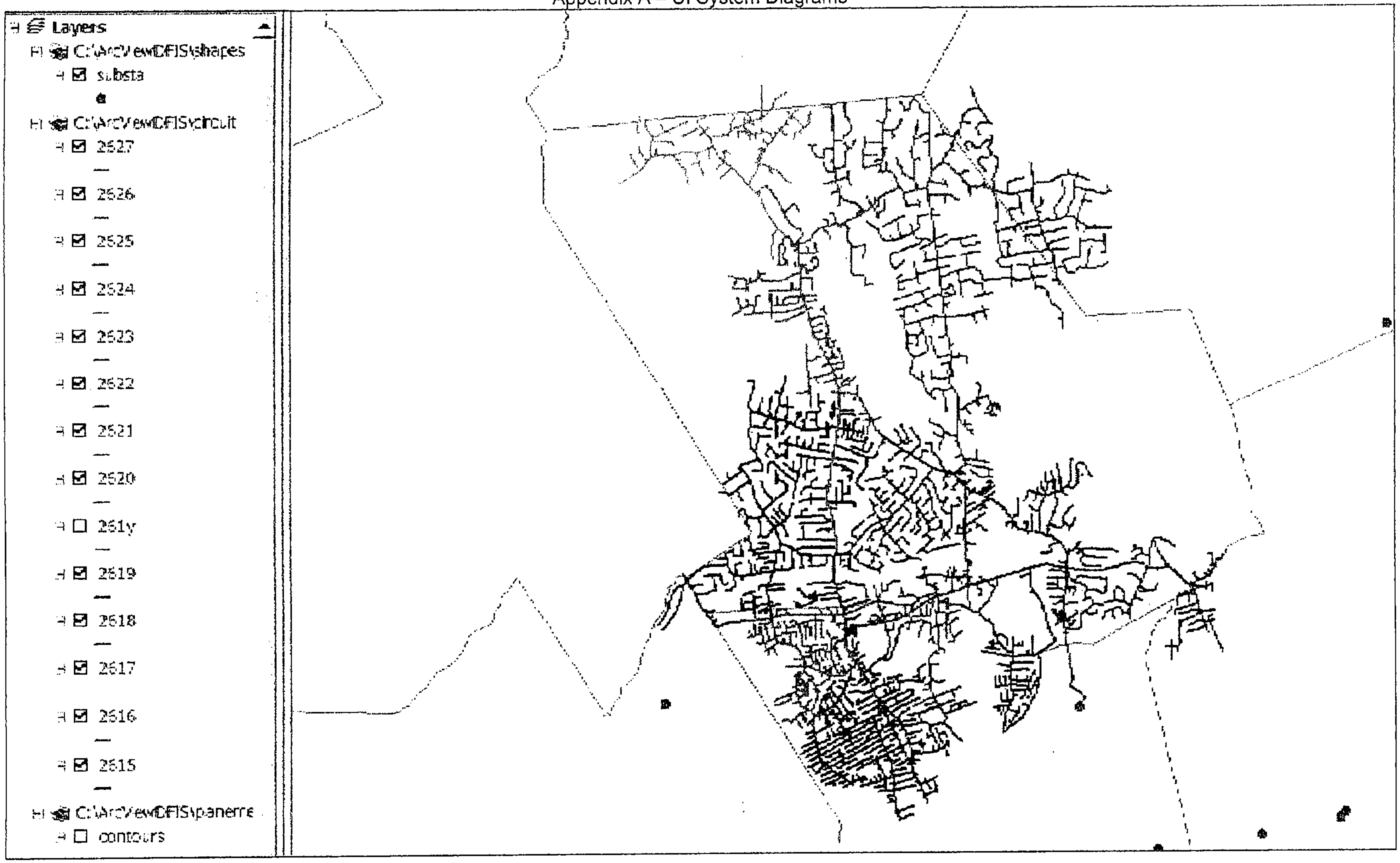

Figure 28 - Old Town 13.8 kV Feeders

Feeders planned to go to new Trumbull substation = 2620 and 2627 (per load forecast spreadsheet)

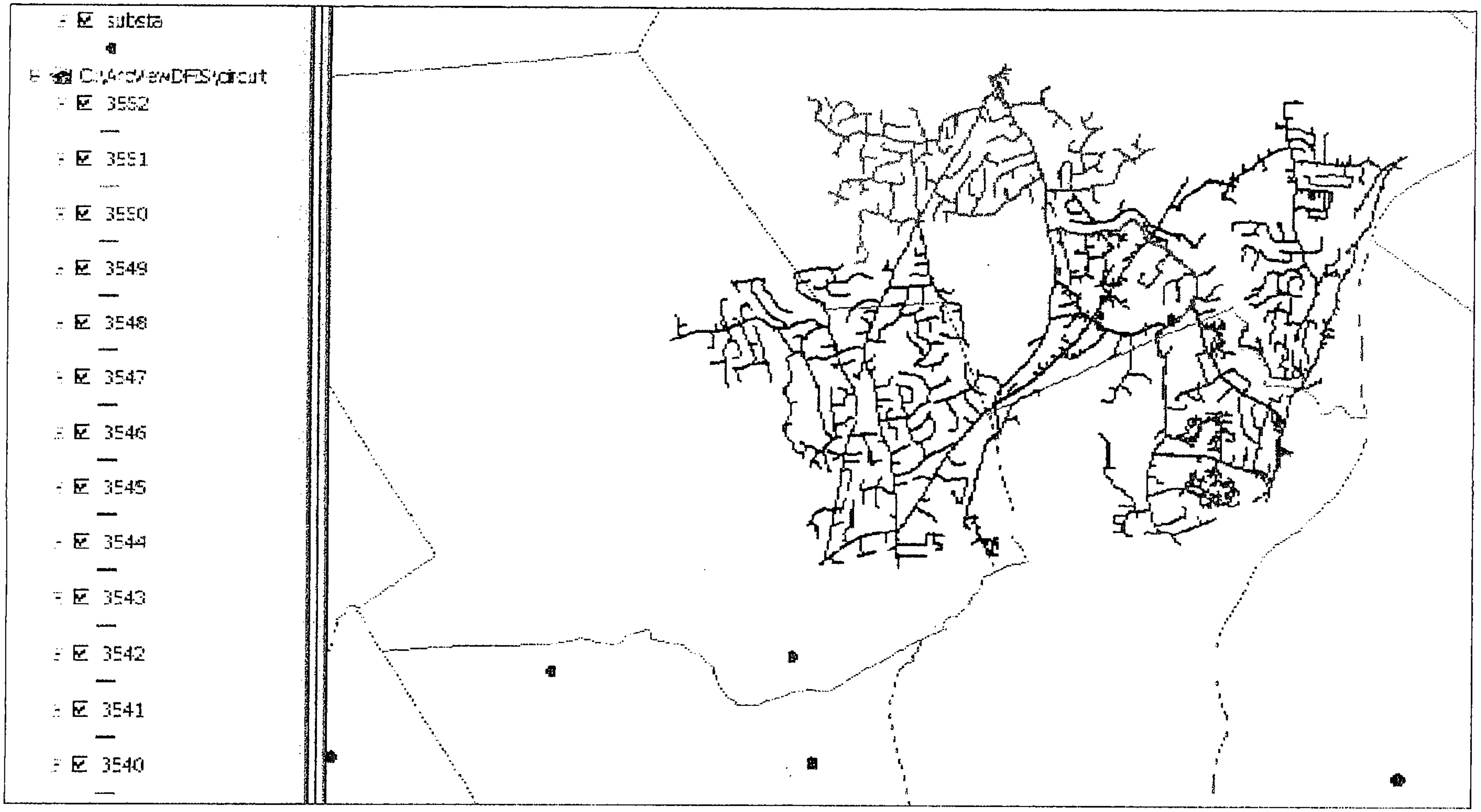

Figure 29 - Trap Falls 13.8 kV Feeders

Feeders planned to go to new Trumbull substation = 3545 and 3547

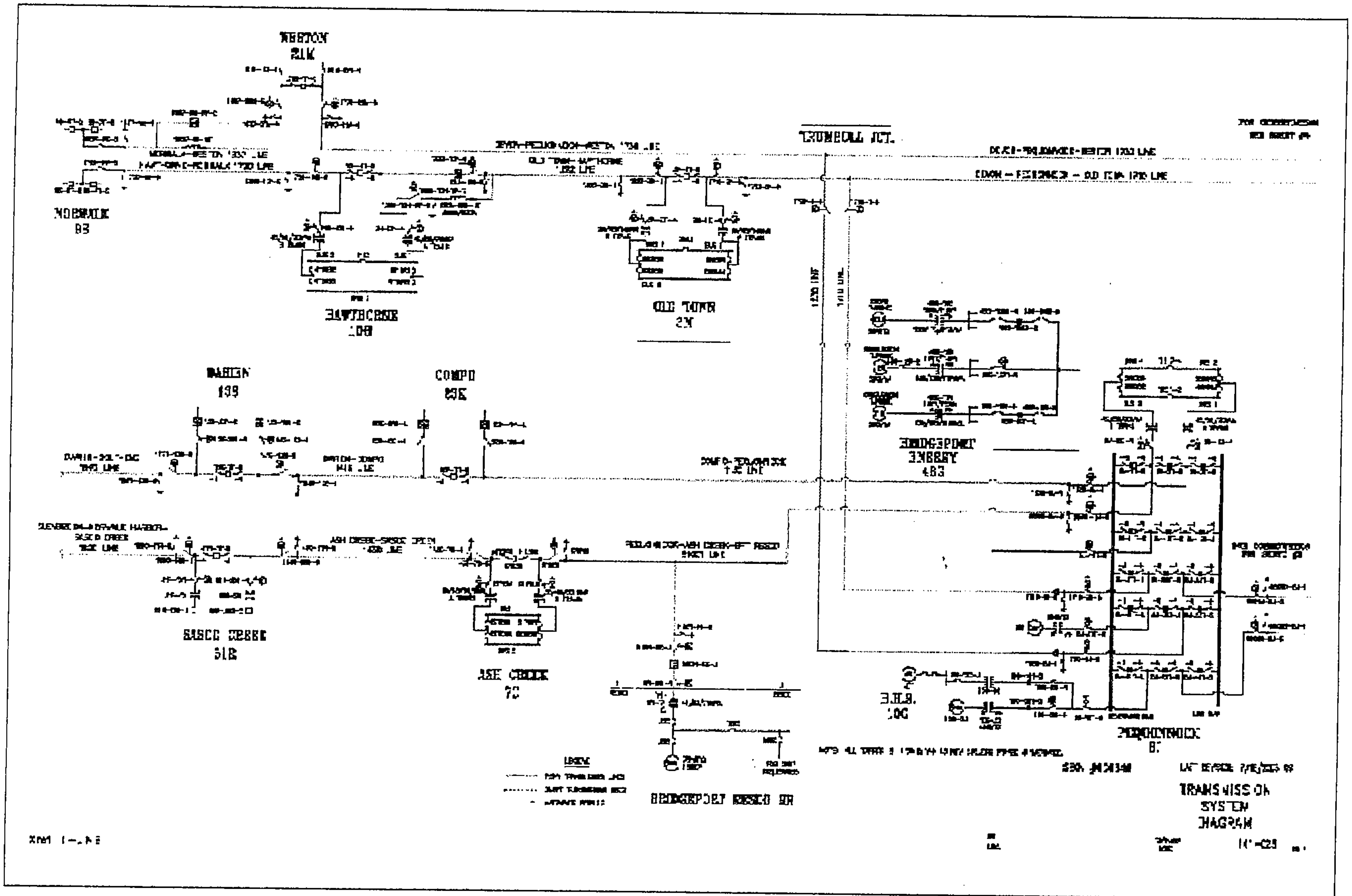

Figure 30 - Old Town Transmission Single Line

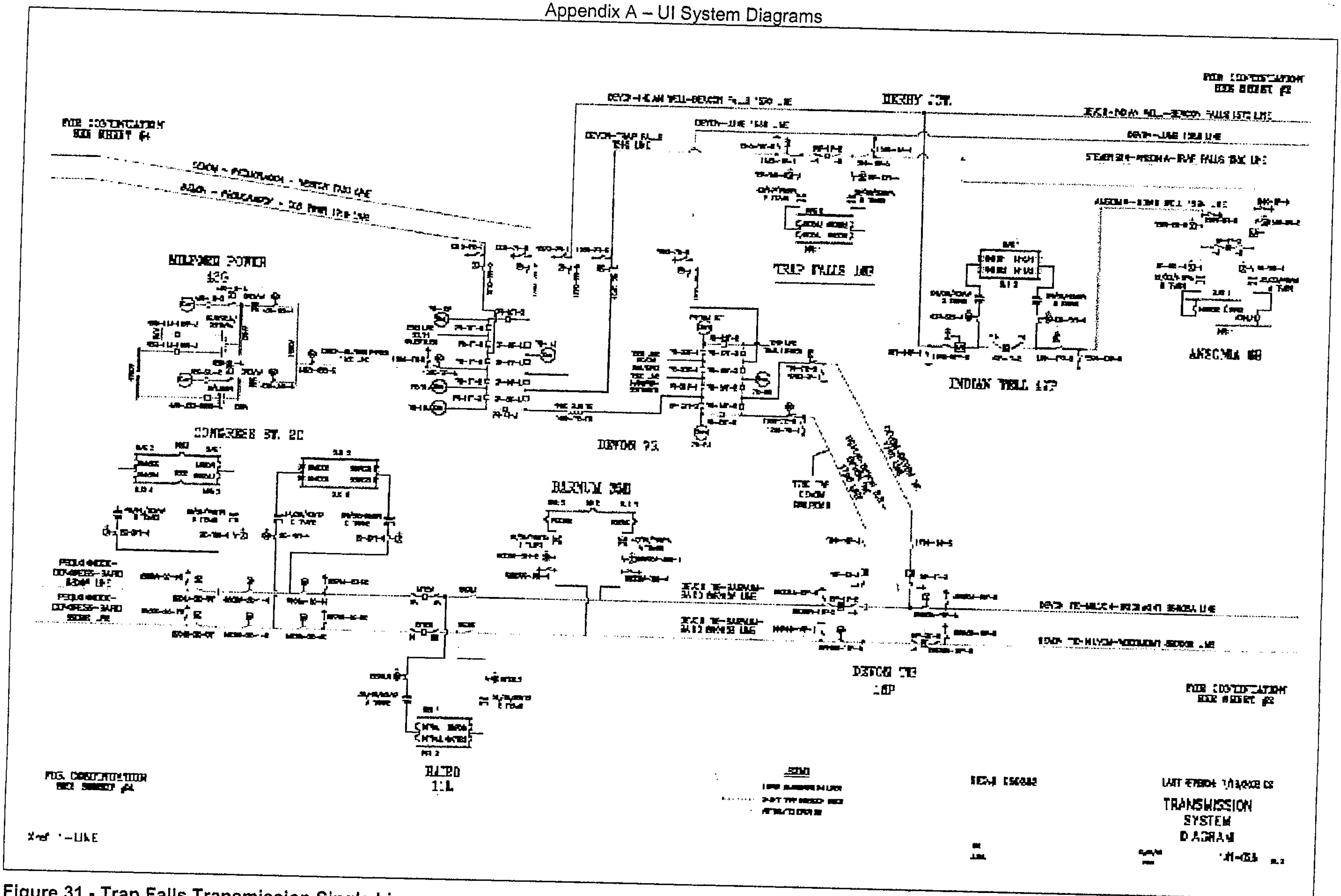

Figure 31 - Trap Falls Transmission Single Line

Appendix B – Weather Normalization Methods

Weather normalization of load data is a mixture of art and science. The procedure that is used varies from one geographic region to another. The weather normalization performed on the load projections in this report largely follow the New England ISO procedure. This is summarized in this appendix and compared to the method used for PJM control area.

ISO NE Formulation

In this formulation, the load is correlated with a weighted 3-day average of a temperature-humidity index (THI) defined as follows:

$$WTHI = \frac{[10THI_d + 5THI_{d-1} + 2THI_{d-2}]}{17} - 55$$

Where

WTHI = Weighted THI
THI_d = THI on day "d"

The THI for a given temperature measurement is defined as

$$THI = 0.5T_{db} + 0.3T_{dew} + 15 \text{ °F}$$

where T_{db} = dry bulb temperature
T_{dew}= dew point temperature

In summary, the WTHI considers the temperature-humidity index for three days running and creates a weighted average that strongly favors the present day but also considers the previous two days. A similar practice is common with utilities in other locations. This WTHI definition is based on 55°F. One might infer from this that 55°F is where it is assumed that cooling load begins to have an effect on the electrical load.

Temperature data for this project came from two sources: UI (Trap Falls substation) and the Bridgeport Sikorsky weather station. The values were quite consistent with the UI data being slightly cooler.

This method was applied to temperature and load data for the last three summers (2002-2004). The WTHI using the UI data was computed for these days and the MW loading was plotted against it for the hottest days of the summer. A WTHI of 26 (UI data) was chosen as the lower cutoff. Below this WTHI, the correlation becomes less distinct.

On the selected hottest days, the slope of the load vs. WTHI is 1.688 MW/degree at Old Town and 1.05 MW/degree at Trap Falls. The trendlines fitted by MS Excel for these values are shown in Figure 32 and Figure 33. Once this trend was known, the loading values were normalized to a design WTHI by adjusting the actual peak load by the difference between the WTHI at the time of the peak and the selected design WTHI.

The UI temperature data was used to determine the most recent sensitivity of load and temperature. The design WTHI was selected from the Bridgeport data. Figure 34 shows the computed WTHI over 55 years for the Bridgeport Sikorsky weather station. The maximums recorded in this time period were nearly 37 degrees. This occurred 4 times in this period, or an average of somewhat less than one such extreme per decade. However, note that two of these events were close together: 1999 and 2001, years that are well-known for extreme power demands. Thus, a WTHI of 37 was chosen as the design value. The weather adjusted loads in Figure 18 and Figure 19 were normalized to this WTHI value using the trend slope determined from the UI data. This value essentially corresponds to an effective temperature of 92°F.

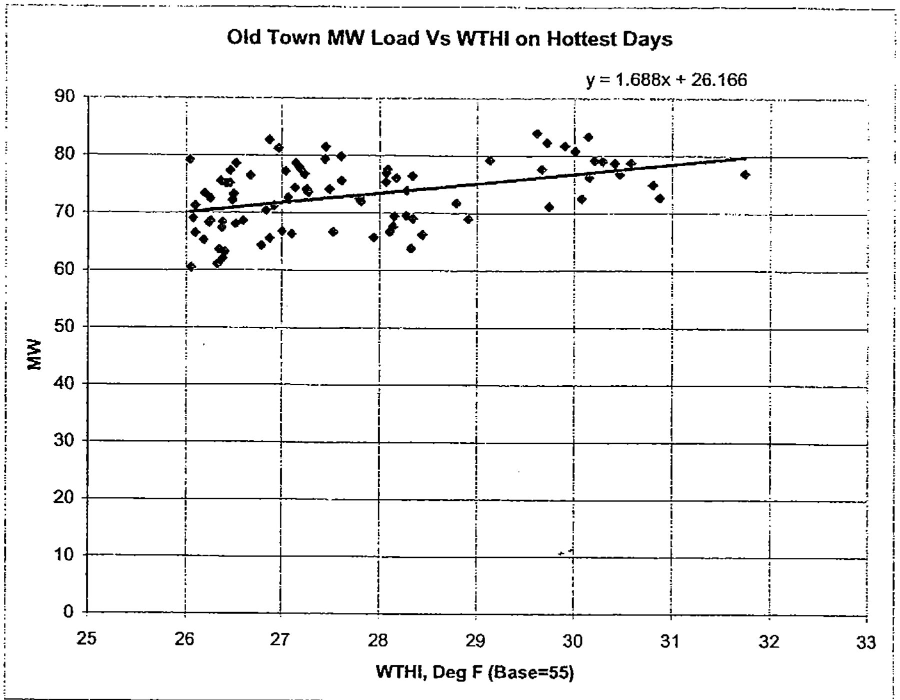

Figure 32. Correlation of MW vs WTHI for Old Town Substation for Hottest Days 2002-2004.

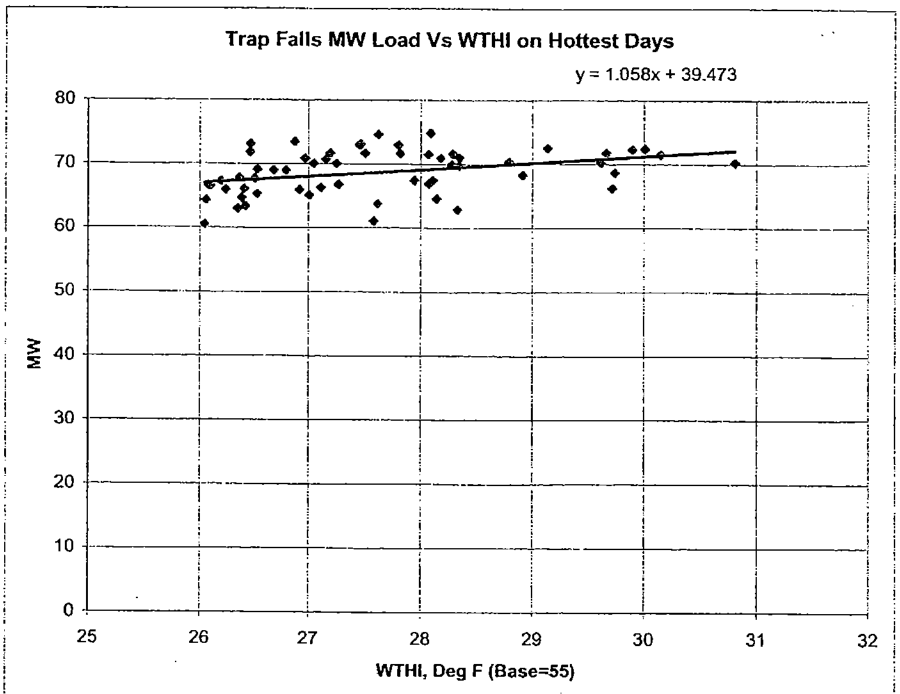

Figure 33. Correlation of MW vs WTHI for Trap Falls Substation for Hottest Days 2002-2004.

For the UI service area, the available temperature quantities were dry bulb temperature and percent relative humidity. A formula for computing the dew point temperature at sea level given these quantities is:

$$T_{dew} = \frac{-430.22 + 237.7\ln(P_{AV})}{-\ln(P_{AV}) + 19.08} \quad °C$$

where

$$P_{AV} = \frac{(RH)P_{SV}}{100} \quad \text{(RH in percent)}$$

$$P_{SV} = 6.11 \times 10^{\left(\frac{7.5T_{db}}{237.7+T_{db}}\right)} \quad T_{db} \text{ in °C}$$

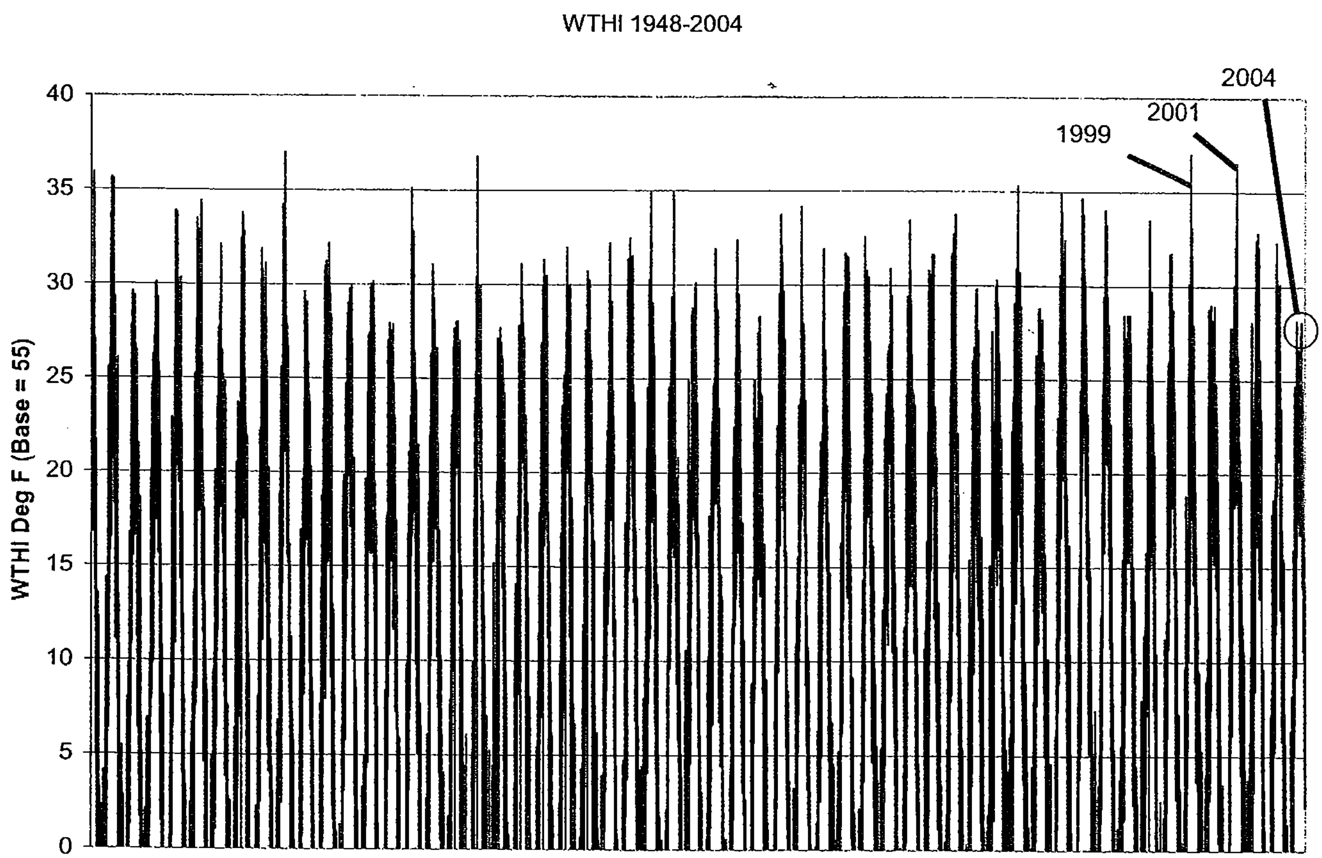

Figure 34. 55-year WTHI computed by NE ISO method for daily maximum temperature and relative humidity readings at Bridgeport Sikorsky station.

This clearly shows that 2004 was a very mild year. The extreme temperatures in 1999 and 2001 that yielded high loading are also quite apparent.

PJM Formulation

The PJM formulae for computing weather normalization for the summer peak in the PJM (East) Control Area are as follows:

Temperature-Humidity Index (THI)

$$THI = DB - 0.55*(1-HUM)*(DB-58)$$

where

DB = Dry bulb temperature (°F)
HUM = Relative Humidity (in per unit)

While this formula is in a different form that the one used by ISO NE, the computed THI is similar. Figure 35 shows a comparison of the values computed by each method. The PJM formulation produces slightly higher THI values by 2-3 degrees on the hotter days, either formulation would seem to be satisfactory.

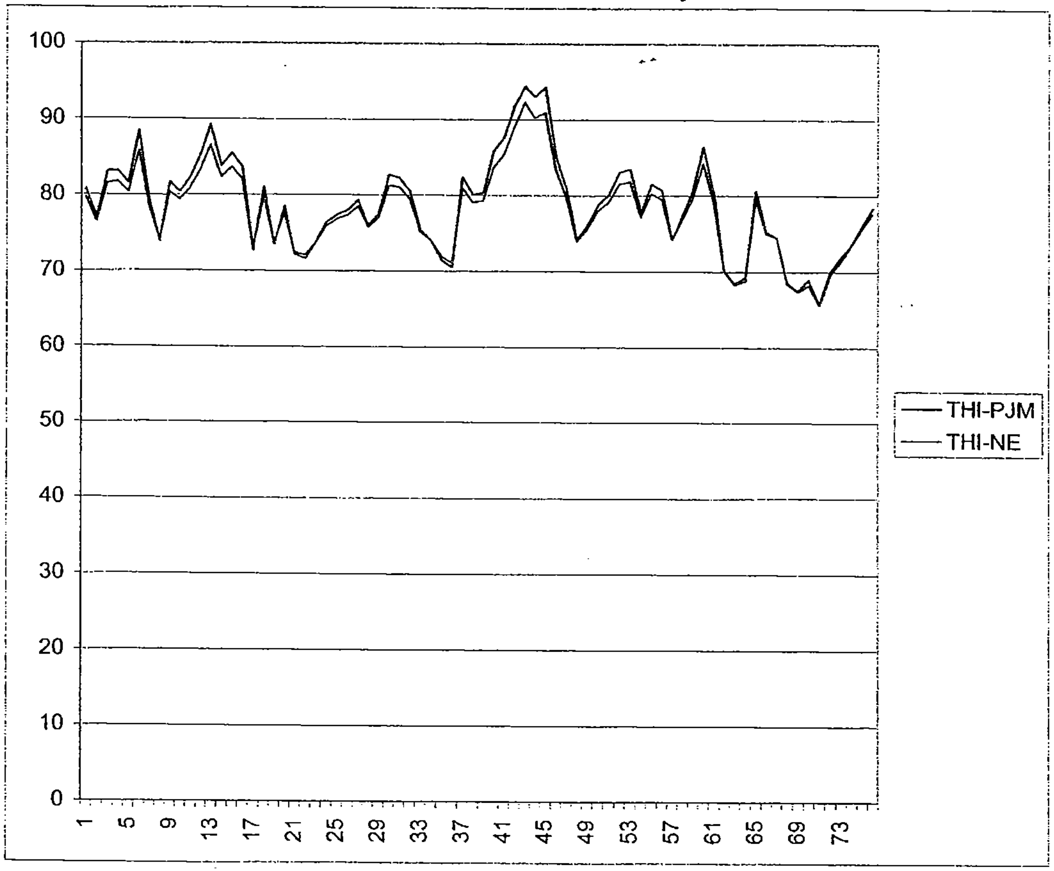

Figure 35. Comparison of THI computed by PJM and NE ISO methods

The next step is to compute the maximum THI (MTHI) for each day between 1400 and 1700 hours. This is a weighted average of three weather stations in the PJM region:

$$MTHI = (5MTHI_n + 3MTHI_p + 2MTHI_w)/10$$

Where $MTHI_n$=Maximum THI (Newark)
$MTHI_p$=Maximum THI (Philadelphia)
$MTHI_w$=Maximum THI (Washington)

Appendix C – Trumbull New Loads 2004 – 2009

Number	Town	Substation Indian Well	Circuit	2004 (kW)	2005 (kW)	2006 (kW)	2007 (kW)	2008 (kW)	2009 (kW)
1	Shelton		516			100	100	50	
2.	Shelton		503			500			
3.	Derby		505			200	500	500	500
4.	Derby		505				200	300	200
5.	Derby		505				75	75	
6.	Derby		504	300					
7.	Derby		503		250				
8.	Shelton		503		100				
9.	Shelton		503	375					
10.	Shelton		510			130			
11.	Derby		503		150				
12.	Derby		505		750	250	250		
13.	Shelton		503		50	100	50		
14.	Shelton		503		250				
15.	Shelton		503		100				
16.	Shelton		500			75			
17.	Shelton		510			100	100		
18.	Shelton		516			750	250		
19.	Shelton		505				500	250	
20.	Shelton		510		75				
21.	Shelton		514			50	50	50	
22.	Shelton		510			500	250		
23.	Shelton		503		300				
24.	Shelton		516			1500	500		
25.	Shelton		512			100	200	200	
26.	Shelton		503				100		
27.	Orange		504			240			
28.	Shelton		500			300	300		

Appendix C – Trumbull New Loads 2004-2009

Project Name	Town	Substation	Circuit	2004 (kW)	2005 (kW)	2006 (kW)	2007 (kW)	2008 (kW)	2009 (kW)
		Indian Well							
29.	Shelton		503				150		
30.	Shelton		503			150			
31.	Shelton		516			500			
32.	Shelton		516				500	500	
33.	Shelton		500			100	100		
			Total MVA=	0.75	2.25	6.27	4.64	2.14	0.78
		Old Town							
1.	Trumbull		2620	1000					
2.	Trumbull		2617	300	400	200			
3.	Trumbull		2622	400					
4.	Trumbull		2624			230			
5.	Bridgeport		2623	200					
6.	Trumbull		2620		750				
7.	Trumbull		2620		750	250			
8.	Trumbull		2617		500				
9.	Shelton		2621			100			
10.	Trumbull		2619			50			
11.	Trumbull		2620		750				
12.	Trumbull		2617		150				
13.	Trumbull		2617				50	50	
14.	Trumbull		2617				300		
15.	Trumbull					1200	400		
			Total MVA=	2.11	3.67	2.26	0.83	0.06	0.00

Appendix C – Trumbull New Loads 2004-2009

Project Name	Town	Substation Trap Falls	Circuit	2004 (kW)	2005 (kW)	2006 (kW)	2007 (kW)	2008 (kW)	2009 (kW)
16.	Shelton		3551	50	50	50			
17.	Shelton		3551		200	200	200		
18.	Shelton		3546	60					
19.	Shelton		3548		250	500			
20.	Shelton		3548			750			
21.	Shelton		3542			80	80	50	50
22.	Shelton		3546				200	200	200
23.	Shelton		3543			250			
24.	Shelton		3543				50		
25.	Shelton		3548			1400			
26.	Shelton		3546			600			
27.	Shelton		3542		300				
28	Stratford		3543			210			
29.	Stratford		3543			50			
30.	Stratford		3543			100			
31.	Shelton		3546				250		
32.	Stratford		3543				100	100	50
33.	Stratford		3543				50	50	50
34.	Shelton		3546					150	
			Total MVA=	0.12	0.89	4.66	1.03	0.61	0.39

Note: Power Factor assumed to be 90%. There is an 0.85 Load Coincident Factor taken on all totals