The response of large industrial energy consumers to four coincident peak (4CP) transmission charges in the Texas (ERCOT) market

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Abstract

Large industrial energy consumers served at transmission voltage in the ERCOT market reduce their consumption up to 4% during intervals in which consumers are charged for transmission services. The response normally lasts two to three hours, since consumers do not know exactly which interval will set one of the four summer coincident peaks (CPs), which are the basis for transmission charges. Thus, the design of transmission prices in ERCOT has been successful in eliciting demand response from that market's largest industrial energy consumers. However, there is no noticeable response during some CPs, reflecting the difficulties in predicting the actual timing of the peak. The response by industrials served at primary voltage to the price signals is insignificant.

Keywords: Electricity pricing; transmission charges; ERCOT

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1. Introduction

When the Electric Reliability Council of Texas (ERCOT) wholesale market was redesigned to foster competition among generators and provide a foundation for retail competition during the 1999-2001 timeframe, the Public Utility Commission of Texas (PUCT) grappled with how to charge consumers for transmission services under the new unbundled market structure. Under the resulting policy, large industrial energy consumers with interval data recorders (IDRs) are charged for transmission services based on the individual consumer's contribution to four coincident peaks (4CPs), i.e., the 15-minute intervals of highest demand on the ERCOT system in each of four summer months -- June, July, August, and September. The total level of compensation provided to transmission owners is approved by the PUCT each year. Transmission costs are then apportioned to each load, or user of the transmission system, based on its share of total demand during these 4CPs. The costs are recovered through levelized monthly charges paid the following year. Revenues from the transmission charges are collected by the retail electric provider (REP) providing electricity to the consumer at the retail level and these revenues are ultimately passed through to transmission owners.

A consumer that can reduce its demand for electricity by 1 MW during each of the four CPs can save about $25,000 in transmission charges the following year, as illustrated in Table 1 for energy consumers in the three largest transmission distribution utility (TDU) services areas. This potential avoidance of transmission charges provides a strong incentive for industrial energy consumers with some flexibility in their operations to engage in "4CP chasing." In 2012, 14 REPs and eight municipal utilities or cooperatives, as well as a number of consulting firms, operated 4CP forecasting services to notify industrial energy consumers of opportunities to reduce their transmission costs by strategically reducing their energy purchases during the summer peaks. (Wattles and Farley, 2012)

Table 1.
Example Savings Calculations for a 1 MW Reduction in Demand during 4CP Periods

	Monthly Charge per Previous Year's 4-CP kW	Annual Savings from a 1 MW demand reduction during 4CP periods		
CenterPoint Energy				
Primary Voltage (with IDR)	$2.1546	$25,855.20		
Transmission Voltage	$2.1187	$25,424.40		
Oncor				
Primary Voltage (with IDR)	$2.5684	$30,820.25		
Transmission Voltage	$2.6368	$31,641.71		
AEP-Texas Central				
Primary Voltage (with IDR)	$1.9250	$23,100.00		
Transmission Voltage	$1.7180	$20,616.00		
Source of rates: http://www.puc.texas.gov/industry/electric/rates/Trans/TDGenericRateSummary.pdf				
Last accessed December 15, 2012. The calculations assume the customer has a power factor of one.				

Despite the significant potential savings, not all industrial energy consumers respond to transmission prices. Some industrial facilities have little flexibility in their operations. A curtailment may impose economic costs upon some consumers in excess of the value of the potential savings in transmission costs. Energy consumers with the ability to easily interrupt or curtail their purchases from the grid and commit to providing an ancillary service to the ERCOT market (i.e., commit to curtail at the request of the system operator to provide an operating reserve) cannot concurrently chase 4CPs. This could limit the response of an interruptible load that had elected to provide an ancillary service in ERCOT's day-ahead market or has an obligation with a load-serving entity through a bilateral arrangement to "be available" to provide a curtailment at ERCOT's request.

Demand response to the 4CPs may also be hampered by difficulties in predicting the CPs. Until a summer month is over, the interval with the highest level of system demand is not known. It is particularly difficult to discern whether a hot day during the first week of a month will indeed set a CP, since weather forecasts for the later days of the month will not yet be widely available, and any available forecasts so early in a month will possess considerable uncertainty. Further, a strong response to a likely CP may move the monthly peak demand to a different 15-minute interval within the same day or to another day.

When the service areas of the investor-owned TDUs were opened to retail competition in January 2002, consumers with a non-coincident peak demand or "billing demand" of over 1 MW were required to have Interval Data Recorders (IDRs) installed. The interval-level measurements obtained from IDRs facilitates the settlement of energy generation transactions and provides a measurement of each large load's contribution to the 4CPs. The IDR threshold was lowered to 700 kW in 2006. (Raish and Linsey, 2004)

Until recently, the contribution of smaller consumers (e.g., residential and commercial energy consumers) to the 4CPs was difficult to cost-effectively measure, so generic profiles were used to approximate their level of demand in given time periods. As a result, there is no direct benefit to an individual residential or small commercial consumer from reducing electricity use during a 4CP. Perhaps this situation will change, once advanced metering systems are more-fully deployed.

On occasion, the staff of ERCOT has provided graphs showing a significant drop in demand from large industrial energy consumers during a 4CP. In previous studies of the response of industrial energy consumers to price signals in the ERCOT market, real-time energy prices were combined with the 4CP transmission prices and consumer response to the combined prices was analyzed. It was apparent that certain customers responded to wholesale market price signals – either the 4CP charges, real-time energy prices, or both. (Zarnikau and Hallett, 2008; and Zarnikau, et. al. 2007) In this analysis, the focus is solely on the 4CP transmission charges.

This paper contributes a more-detailed analysis of consumer response to 4CP in ERCOT than has been conducted to date. In Texas, a better understanding of demand response is critically important in light of ERCOT's "energy-only" market design which relies extensively on market forces to balance supply and demand. As low natural gas prices have impaired the profitability of constructing new power plants in recent years, means of reducing peak demand and preserving system reliability through demand response have become increasingly important. It is anticipated that this analysis will also prove instructive to those faced with the task of designing tariffs for transmission service for other markets or utility systems. An important consideration in the design of transmission prices is the impact such pricing will have on system demand.

The following section uses a regression approach to explore the degree to which these two groups of large energy consumers respond to the transmission prices. Section III estimates the response of consumers served at transmission voltage to the 4CP-based transmission prices using an historical baseline approach. The final section summarizes our findings and offers some observations.

II. Do Large Consumers Respond to Transmission Prices?

As noted above, large consumers of electricity in ERCOT with their interval-level consumption metered with IDRs can realize significant cost savings by reducing their purchases during the 4CPs. But, to what degree do they indeed take advantage of this opportunity and respond to this price signal?

To explore this question, 15-minute interval aggregated load data for the two groups of energy consumers thought most likely to respond to 4CP events were obtained from the staff of ERCOT. These groups were 1) consumers with a non-coincident peak demand (billing demand) that exceeded 1 MW at least 10 times since January 2002 and were served at transmission voltage and 2) consumers served at primary voltage with a peak demand meeting these same criteria. The former group includes many very large refineries and chemical production facilities along the Gulf Coast. Data for the period from January 2007 through mid-2012 was used in this analysis.

Regression models were used to screen whether demand by the two groups of consumers during summer afternoons were affected by the transmission price signals. The observations used in the estimation were confined to the nine 15-minute intervals from 3:00 pm through 5:15 pm (intervals 61 through 69) during weekday summer months. In recent years, the monthly CPs during the summer have always fallen within this period.

Because the timing of the CPs cannot be perfectly predicted (and a response by consumers to an anticipated CP period could shift CP to a different interval), we are interested in detecting both 1) any reduction in demand during an actual CP and 2) during other intervals when a CP might have been considered probable. To determine the intervals when consumers might have thought a CP was likely, a logistic regression model was used to estimate the historical relationship between a CP and a set of explanatory variables. Variables representing the month of the year and interval within the day were included to capture seasonal and diurnal factors affecting electricity use. The variable *Interval61_62_63* represents the period from 3 p.m. to 3:45 p.m., while *Interval 64_65_66* covers the period from 3:45 p.m. to 4:30 p.m. Binary monthly variables were used to represent the months of June, July, and August. The real-time market price of electricity was included as an explanatory variable, to recognize that the response by consumers to a high price could reduce the odds of setting a CP, *ceteris paribus*. Or, perhaps a high price would signal the possibility of a CP to a consumer monitoring market prices. The real time energy price is the market-clearing price of balancing energy during the period in which ERCOT had a zonal market structure, and the zonal average of locational marginal prices for the period since ERCOT adopted a nodal market structure. Energy prices (expressed in dollars per MWh) were obtained from ERCOT's website. Total system demand during the same interval of the previous day was included to recognize that patterns in demand across consecutive days may affect the likelihood of a CP, or the perception that one might occur. Finally, since summer peak loads are largely determined by air conditioning usage in Texas, a variable was constructed to represent the difference between the actual temperature in a central location within the ERCOT market (Austin) for a given interval and the highest temperature reading during the given month. Since interval-level temperature data were not available, it was assumed that all intervals within each hour had the same temperature. Of course, at any given time prior to the end of the month, a consumer will not have complete information about hourly temperatures for the entire month. Thus, our use of this variable implicitly assumes that a consumer has access to – and responds -- to reasonably accurate weather forecasts. As noted earlier, the uncertainty surrounding weather forecasts makes it more difficult to predict CPs that occur early in a month.

Estimation results are presented in Table 2. As one would expect, the greater the gap between the temperature of an interval and the highest temperature reading for the month, the lower the odds of setting a CP. An increase in energy prices and an increase in system load during the previous days tend to raise the odds of reaching a CP, holding other variables constant. The dummy variables representing the month of the year and time of day tended to not have significant impacts. The high percent concordant suggests the predictive power of the model is quite satisfactory.

Table 2

Estimation Results from Logistic Regression Model used to Determine Probability of a CP

	Odds Ratio Estimate (p-value in parentheses)
Variable or Statistic	
Temperature Relative to Monthly Highest Temperature	-0.741 (<.0001)
Energy Price in Real-Time Market	1.001 (.0248)
June Dummy	0.426 (.1919)
July Dummy	0.439 (.2081)
August Dummy	0.45 (.2707)
Interval61_62_63 Dummy	0.077 (.0161)
Interval64_65_66 Dummy	0.79 (.6032)
System Demand Previous on Same Interval of Previous Day	1.001 (.013)
Percent Concordant	94
Percent Discordant	5.2

From the logistic regression model, the estimated probability of a CP during every interval of the estimation period (summer weekday late afternoons from 2007 to mid-2012) was obtained. Some scaling was performed to ensure that the probability of setting a CP over all intervals in a given month was equal to one. A new variable, *NearCP*, was created to represent intervals when the estimated probability was greater than 1.4%, yet a CP was not actually set. The 1.4% cutoff point was adopted since it resulted in numbers of 15-minute intervals with a high likelihood of a CP (but no actual CP) ranging from 6 per month (1.5 hours) to 29 per month (7.25). It was thought unlikely that a consumer hoping to avoid transmission charges would respond by curtailing its energy use in a greater number of periods than this.

Having now constructed a variable to represent intervals when the response of a consumer chasing CP's might have been expected to respond, a set of simple linear models was used to detect whether the presence of an actual CP or *NearCP* had any detectable effect on the electricity consumption of either group of large energy consumers. The dependent variables represented the energy consumption of the two groups, expressed in kWh per 15-minute interval. The explanatory variables were the real-time energy price (dollars per MWh), the presence of a CP (coded with a 1 if the interval was a CP and 0 otherwise), the *NearCP* (coded with a 1 if the interval had a high probability of setting CP and 0 otherwise) and variables representing the month of the year and interval within the day to capture seasonal and diurnal factors affecting electricity use. Again, the variable *Interval61_62_63* represents the period from 3 p.m. to 3:45 p.m., while *Interval 64_65_66* covers the period from 3:45 p.m. to 4:30 p.m. The real time energy price (the same variable as was used in the logit model) was used to distinguish the response by consumers to a high market price of electricity generation from a 4CP-based transmission price. The temperature at a central location within the ERCOT market (i.e., Austin) was also used a as control variable.

Regression results are provided in Table 3. In the regression model which seeks to explain interval-level demand of energy consumers served at primary voltage, the high p-value on the coefficient estimated for the variable representing the CP interval suggests no significant response by primary voltage customers to CPs, after controlling for the effects of real-time market prices, temperature, and time-of-day and month-of-year effects. Similarly, the effect of a

NearCP upon the energy purchased by consumers served at primary voltage does not significantly differ from zero. In contrast, a CP reduces the consumption of consumers served at transmission voltage by 36,861 kWh on average and after controlling for the effects of the other variables considered. A *NearCP* reduces the energy consumption of consumers served at transmission voltage by a lesser, but still significant, amount – perhaps reflecting the success of these consumers in identifying a true CP. Similar results were obtained when the variable representing the 15-minute interval of the CP was replaced with a variable representing the day in which the CP occurred. It is also interesting to note that the consumers taking service at transmission voltage are quite responsive to real-time energy prices, whereas the consumers served at primary voltage do not appear to react to changes in wholesale electricity prices. While the electricity demand of consumers served at primary voltage is quite temperature-sensitive, temperature changes have no significant impact on the electricity demand of the generally-larger industrial energy consumers served at transmission voltage.

Table 3
Estimated Impacts of CP Events and Other Factors on Load (in kWh) of Customers Served at Transmission and Primary Voltages
(p-values are provided in parentheses.)

	Transmission Voltage Consumers (kWh/Interval)	Primary Voltage Consumers (kWh/Interval)
Variable or Statistic		
R^2	0.101	0.256
Intercept	827,777 (<.0001)	447,267 (<.0001)
CP Interval	-36,861 (.0003)	3,403 (.5313)
NearCP Interval	-7,813 (.0038)	764 (.596)
Energy Price in Real-Time Market	-9.6725 (<.0001)	1.489 (<.2063)
June Dummy	34,690 (<.0001)	16,611 (<.0001)
July Dummy	35,493 (<.0001)	12,516 (<.0001)
August Dummy	37,608 (<.0001)	21,865 (<.0001)
Austin Temperature (degrees F)	-13.533 (.8979)	1,132 (<.0001)
Interval61_62_63 Dummy	6,653 (.0002)	14,108 (<.0001)
Interval64_65_66 Dummy	1,305 (.4614)	7,708 (<.0001)

III. Estimating the Impacts with an Historical Baseline Approach

Graphical analysis illustrates that the response to a CP is quite pronounced on certain days. Figures 1 and 2 compare actual interval-level energy consumption by transmission voltage consumers against a baseline usage pattern. The baseline was constructed by averaging the load levels exhibited by this group of consumers over the five previous weekdays. Weekend days were not included in the baseline calculations, since no CPs were set on weekends during the timeframe studied here. Near-CP days were also excluded from the baselines, as these days tend to have CP responses, so including them would blur the picture. The historical baseline was then scaled, so that the total energy up to 15:00 (3 p.m.) for the baseline matched the total energy consumed up to 15:00 on the CP day. On the two days represented in the first two figures, the response to the anticipated CP appears obvious. While the CPs on these two days actually occurred during intervals 67 and 68 -- ending at 16:45 (4:45 p.m.) and 17:00 (5 p.m.), respectively -- the response started earlier and diminished later than the actual CP interval, since the consumers did not know which interval would set the CP. Thus the period of response is typically 2 or 3 hours.

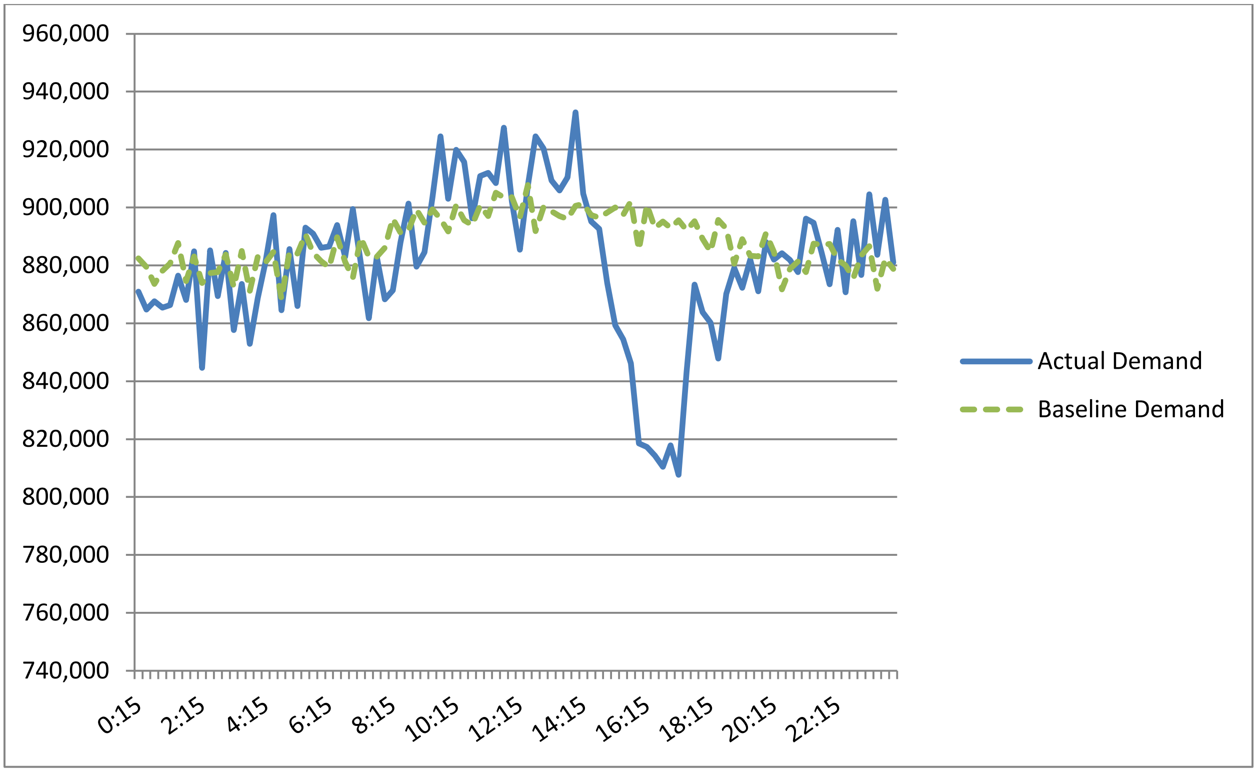

Fig. 1. Energy Consumption (in kWh) by Transmission Voltage Customers on June 16, 2008, Contrasted against Baseline Energy

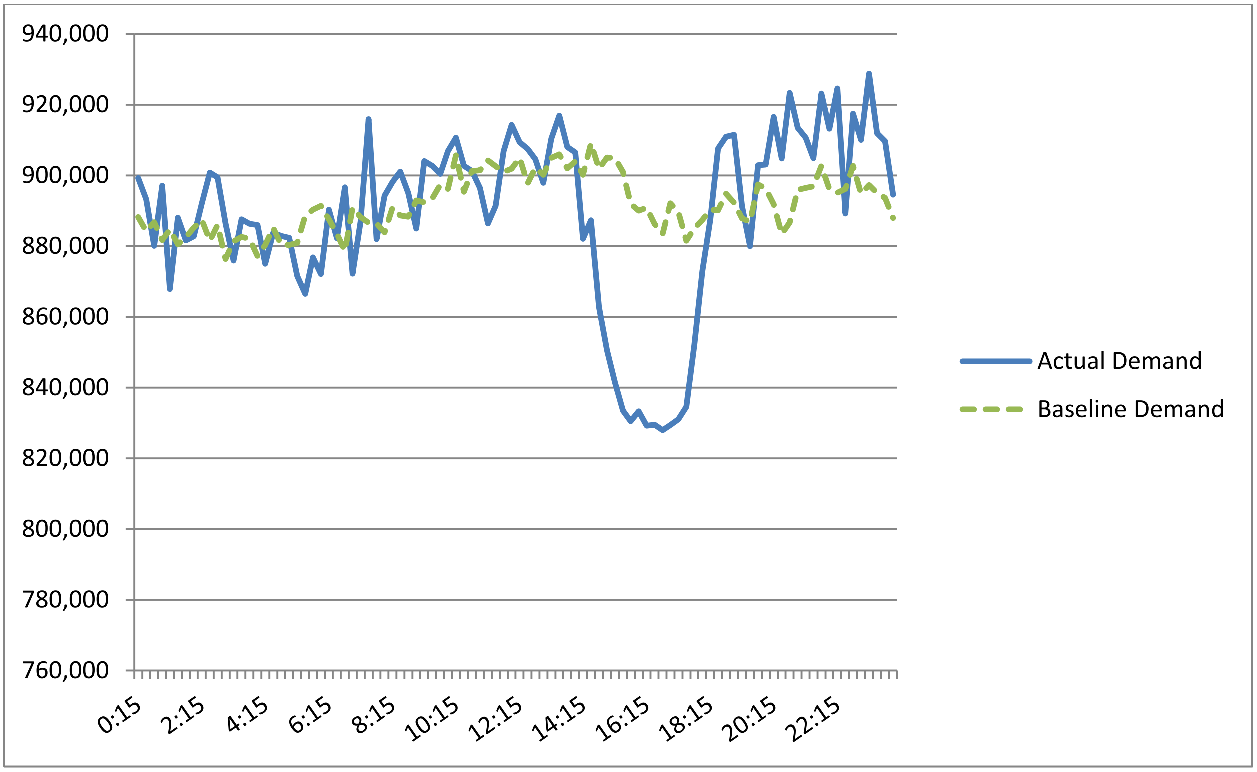

Fig. 2. Energy Consumption (in kWh) by Transmission Voltage Customers on June 26, 2011, Contrasted against Baseline Energy

On some days, it appears as though this group of consumers failed to anticipate the CP, as demonstrated in Fig. 3. The CP was reached in the interval ending 16:45 on the September 2008 CP. A lack of response was sometimes exhibited when the CP occurred early in the month, at which time weather conditions and the resulting load levels for the entire month would be difficult to anticipate.

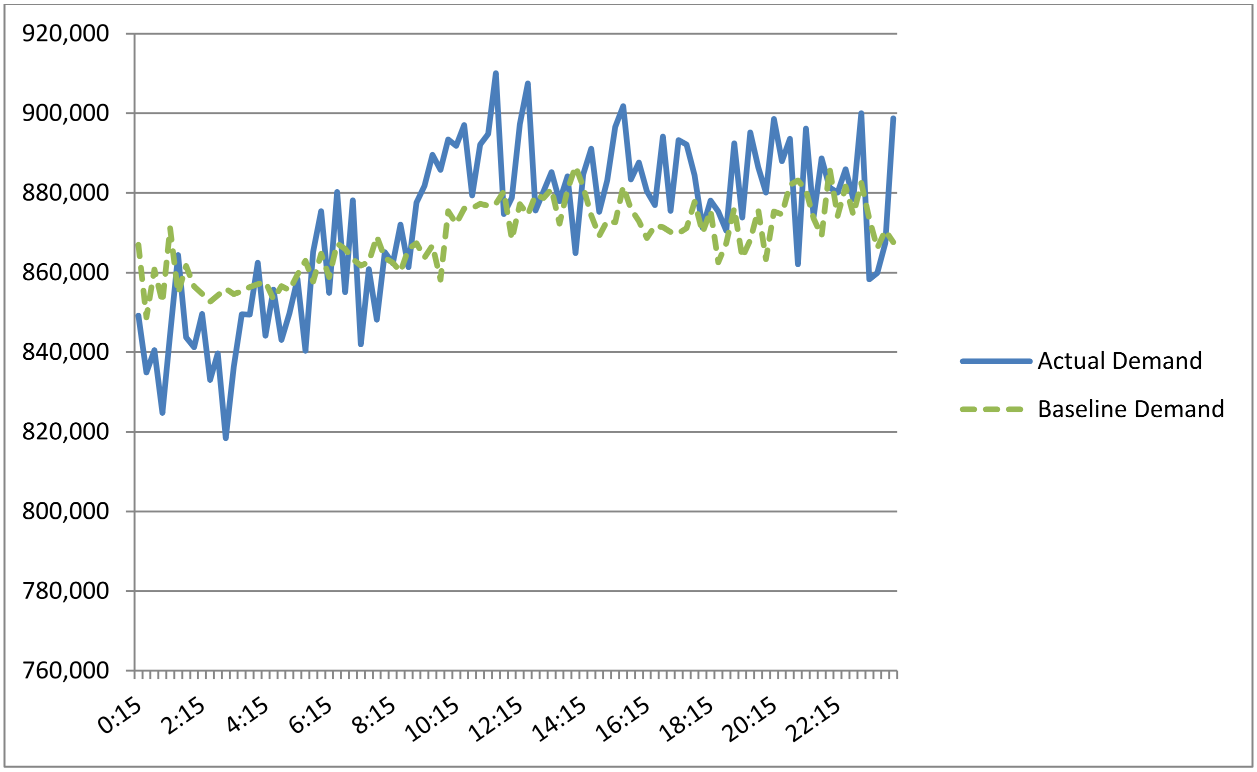

Fig. 3. Energy Consumption (in kWh) by Transmission Voltage Customers on September 2, 2008, Contrasted against Baseline Energy

Finally, there are some days when both the load for the day containing the CP interval and the baseline load show a significant drop during the late afternoon, as can be seen from Fig. 4. Presumably, this reflects a situation where consecutive days appear to be equally likely to set the CP, and consumers engage in a pattern of reducing their energy consumption during the late afternoon in each of the days.

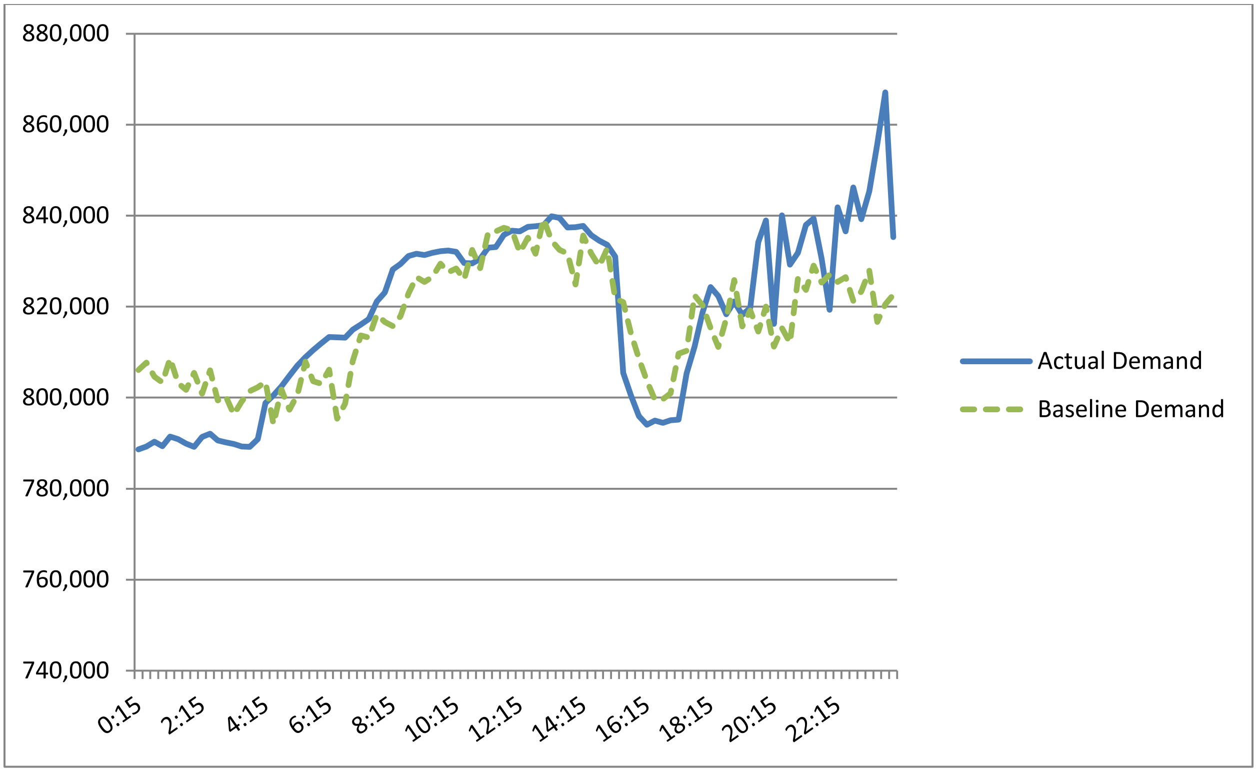

Fig. 4. Energy Consumption (in kWh) by Transmission Voltage Customers on June 21, 2010, Contrasted against Baseline Energy

The estimated demand reduction during each of the CP events from 2007 through mid-2012 is provided on Table 4. A baseline constructed from the five previous weekdays (excluding near-CP days) was again used to the estimate the load pattern which would have prevailed had a CP not been expected. If the previous month's CP was among the five previous weekdays – as was the case for the August 2008 CP, then the previous month's CP was removed from the baseline calculation and replaced with an earlier day.

Table 4.
Estimated Demand Reduction During CP Intervals

Year	Month	Day	Interval	Actual kWh	Baseline kWh	kWh Drop within Interval	Demand Reduction in MW	Percentage Drop in Load Served at Transmission Voltage
2007	6	19	16:45	921,415	909,321	-12,094	-48	-0.53%
2007	7	12	16:30	867,977	895,888	27,910	112	1.25%
2007	8	13	15:30	885,253	906,844	21,591	86	0.95%
2007	9	7	16:00	848,865	902,231	53,366	213	2.37%
2008	6	16	16:45	810,464	895,107	84,643	339	3.78%
2008	7	31	16:45	817,820	848,674	30,854	123	1.45%
2008	8	4	17:00	809,458	877,318	67,860	271	3.09%
2008	9	2	16:45	894,133	871,420	-22,713	-91	-1.04%
2009	6	25	16:15	755,751	821,269	65,518	262	3.19%
2009	7	13	17:00	782,326	816,379	34,053	136	1.67%
2009	8	5	16:00	770,848	839,342	68,493	274	3.26%
2009	9	3	16:00	808,405	846,666	38,262	153	1.81%
2010	6	21	16:45	794,491	799,680	5,189	21	0.26%
2010	7	16	16:30	813,729	871,681	57,952	232	2.66%
2010	8	23	16:00	779,120	802,858	23,738	95	1.18%
2010	9	14	16:45	785,135	850,913	65,778	263	3.09%
2011	6	15	17:00	806,468	893,428	86,959	348	3.89%
2011	7	27	16:30	824,147	902,259	78,112	312	3.46%
2011	8	3	17:00	819,712	910,745	91,033	364	4.00%
2011	9	2	16:30	796,848	863,959	67,111	268	3.11%
2012	6	26	16:30	829,475	886,217	56,743	227	2.56%
2012	7	31	17:00	723,581	776,613	53,032	212	2.73%

Response to transmission prices appear to be generally increasing over time. In recent years, consumers served at transmission voltage reduced their electricity purchases up to 4% during a summer CP, if a baseline calculation using previous days is used to quantify the impact.

The average energy reduction over all 22 CP events reported in Table 3 is 47,427 kWh. This is higher than the 36,861 kWh energy reduction implied by the coefficient estimate presented in Table 3, which controls for the effects of market prices. Relatively high prices may be expected during a summer peak and some large industrial energy consumers in the ERCOT market purchase energy with pricing based upon real-time energy prices, as confirmed by the regression results presented in Table 3. Thus some of the demand reduction estimated against an historical baseline may actually be attributable to consumer response to a high energy price. The regression approach strives to separate the influences of these two motivations for demand response, whereas the historical baseline approach does not.

IV. Conclusions

Industrial energy consumers served at transmission voltage reduce their energy purchased by up to 4% in response to a CP – the basis for recovering transmission costs from consumers in the ERCOT market. Given that ERCOT's total annual system peak demand is slightly over 66,500 MW, a reduction of 364 MW (the largest demand reduction estimated during a CP using an historical baseline) impacts ERCOT's summer peak by less than six-tenths of one percent. During peak, consumers served at transmission voltage contribute about 5.4% of ERCOT's total demand.

Responsiveness to transmission prices has generally increased over time. The magnitude of the response appears to be related to the certainty or predictability of the timing of the CP.

As ERCOT strives to maintain reliability under its energy-only market structure, this approach to transmission pricing is one market feature with considerable value as a source of demand response. An expansion of direct 4CP pricing of transmission services to smaller loads (e.g., residential and commercial customers) should be considered, now that advanced meters have been widely deployed in the ERCOT power region. Technology which will facilitate the response of consumers to likely peaks should be encouraged, including better communications, control, and metering infrastructure.

The estimates presented here – ranging from negative values, suggesting an absence of any response, up to 364 MW -- are lower than the demand reduction of 500 MW that ERCOT commonly assumes as a response to both 4CP pricing and high real-time prices during the peak summer hour of the year. Yet, this analysis is confined to large industrial energy consumers that purchase power at transmission voltage. Additional demand reduction during peak periods comes from demand response programs implemented by municipal utilities or rural electric cooperatives within the ERCOT power region and programs within the competitive retail market operated by REPs involving smaller loads. Consequently, the demand reduction estimates presented here appear to be compatible with ERCOT's planning assumption.

Issues surrounding the appropriate method to use for the allocation and recovery of transmission costs frequently arise in rate cases and in market design. There are great differences in how each of the world's restructured markets have approached the problem of recovering the cost of transmission services from load-serving entities and industrial energy consumers. (PJM, 2010) If a prominent objective of rate design or market design is to encourage demand response during peak periods, ERCOT's experience demonstrates that a 4CP approach may prove valuable.

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