Analysis of temperature changes effects on electricity consumption in Fars province

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Abstract

Purpose: Climate change is one of the factors that effect on electricity consumption behavior and changes in load of the network. Meanwhile temperature is the most important factor because the use of heating and cooling devices in large scale.

Methods: In this paper calculate the effects of air temperature fluctuations on electricity consumption with the help of temperature coefficient and Weighted-population index take places. Then the network load dependency from air temperature changing analyzed.

Result: After that with using of HDD and CDD indexes load sensitivity to air temperature in cooling and heating period of the year calculated. Analyses of elasticity coefficient of load and air temperature are the last step to monitor the fluctuations in electricity consumption in hot and cold weather.

Conclusion: Also comparing seasonal temperature variations with load table and temperature correlation coefficients shows very close relationship between these two. Correlation coefficient is near 0.90 in several month of the year.

Key words: air temperature changes, Fars load network changes, Weighted-population index,

Introduction

geographical location, climate variability, long hot season beside heavy industries and agricultural boom, the province has become one of the largest consumers of electricity. The important factors affecting power consumption is the main concern for the planners of the electricity industry in the province. Analyzing The pattern of consumption, the effect of air temperature and environmental conditions and also industrial development and population growth in electricity consumption , Can be a good way for programmers to control the growth of power consumption and proper strategy for the optimal use of electricity (power management).air temperature variations increases heating and cooling devises operation so it has deep effects on Fars network load .to analyzing the behavior of the network, we are using the simultaneous electricity load information during 2003-2012.Moderate growth of annual energy consumption and the peak of electricity load in Fars network during the year studied are7.6 and 9.3 percent respectively based on dispatching center of Fars regional Electric company in 2012.

Electricity load in Fars network is effecting by high seasonal changes because of specific climate condition in the region. Thus load peak in summer is almost 2 times higher than winter and so the result is variation in network load during these two period. Therefore we can divide Fars in two different parts to show weather fluctuations, warm period (April to October) and cold and moderate period (November to March). In warm period and with the use of cooling devises in most cities, cooling load is the most effective factor in using electricity and load peak in network. (Cooling load is creating by using cooling devises in hot weather). In cool period of the year and with suitable environmental condition in the region, lighting load is floating on the network as the most effective factor. In this paper, the effects of temperature change on electricity consumption and load variations are studied. To reach this aim, we calculate network load variation index and province temperature coefficient.one of the most important studies in the world is “Impacts of climate change on electricity consumption” from Aroonruengsawat and Auffhammer [1]. This study simulates the impacts of higher temperatures resulting from anthropogenic climate change on residential electricity consumption for California. Flexible temperature response functions are estimated by climate zone, which allows for differential effects of days in different temperature bins on households’ electricity consumption. The estimation uses a comprehensive household level dataset of billing data for California’s three investor-owned utilities.

Materials and Methods

General characteristics of Fars Province

It is one of the 31 provinces of Iran. It's located in southern part of the country. The province with an area of about 122,608 square kilometers is the fifth largest, with a population of 4,528,513 people, the fourth most populous province in Iran. According to statistics Shiraz with its suburbs, has a population of 1,749,926 people, is the most populous city in the province. Other populous cities of the province are Marvdasht, Kazeroon, Jahrom, and Fasa noted.
Fars Province in the south-central region between the orbits of 27 degrees and 2 minutes and 31 degrees and 42 minutes north latitude and 50 degrees 42 minutes and 55 degrees and 38 minutes east of the Greenwich meridian is located. Its next to Isfahan and Yazd from the north, Bakhtyari and Bushehr from the west, Hormozgan from the south and Kerman from the east.
According to the latest divisions, May 2012, Fars with Shiraz as the capital, including 29 city, 94 towns, 204 villages. Cities in fars are: Abadeh, Arsanjan,Estahban, Eghlid, Bavanat, Pasargad, Jahrom, Khoram Bid, Khonj, ZarrinDasht, Darab.,Sepidan, Shiraz, Frashbnd, Fasa, Firouzabad, QyrvkarzynKazeroun, Lar, Lamerd, marvdashtmamasani, Neyriz. Figure 1 Shows Fars location in Iran.

Fig1. Fars location in Iran

Air Temperature generally in Iran and particularly in Fars is a function of height, latitude and the amount of moisture in atmosphere. Effect of height in temperature is more visible than latitude. In the thermal regime of Fars, January with the average temperature around8.2 ° C and July with 31.7° C are the coldest and warmest months of the year .Fars average annual temperature is17.8 ° C and its being warmer from West to East and from North to South. Temperature rise from West to East because of the mountains in west and from north to south is due to the sun angle.
We have three different climates in the province; there is a mountainous region in North and North West with mild winter and cool summer. A rainy and cold winter with rough, hot and dry summer is the sign of central regions. In South and Southeast due to the low altitude of the mountains, we have few rainfalls in winter, spring and summer with a moderate winter and very hot summer.

Data used

Data used in this paper are weather information (air temperature) and simultaneous electricity load in Fars which are after categorized and division; we calculate the probable connection between these two factors.

Methods

comparing among Temperature fluctuations and changes in power consumption is the main approach of this research. Now to get familiar with the procedure in this Article, all calculus method will be explained briefly. correlation between energy and temperature after Calculating the correlation coefficient between energy consumption and air temperature we want to recognize whether they have any correlation with each other or not. Then we calculate temperature coefficient of the region with the use of weight – population coefficient in the province and finally the article has been completed with the calculation of HDD and CDD indices. So this is the functions of temperature index (TI) and weight – population coefficient of Far [2].

$$TI_t = \sum_{i=1}^{7} T_{ti} W_i \quad (1)$$

TI_t= temperature Coefficient on day 't'
T_{ti}= Maximum temperature of day 't' in 'i' meteorological station
W_i= weight – population factor of the Province Meteorological Stations which is calculated as follows:

$$W_i = \frac{p_i}{\sum_{i=1}^{7} p_i} \quad (2)$$

p_i= Population of city 'i' which is under study to calculate temperature index (TI)

HDD, CDD indices

To calculate the heating and cooling load in the network with the use of temperature index (TI), first of all we should calculate the heating degree day (HDD) and the cooling degree day (CDD) as follows [3].

$$CDD = max(TI - TI^{*}) \quad (3)$$

$$HDD = max(TI^{**} - TI) \quad (4)$$

TI^{*}And$TI^{**}$is The basis heating and cooling air temperature, respectively, which can be equal ¬ or different based on the level of thermal comfort system.

Elasticity coefficient

Elasticity coefficient here shows the sensitivity of network's load to air temperature variations. This means that how the fluctuation in power consumption is acting in hot and cold weather.

In order to evaluate the relationship between elasticity coefficients, changes in network load and heating and cooling systems, the following functions can be used [3].

$$\varepsilon_{CDD} = \frac{CDD}{L_{CDD}} f'(CDD) \quad (5)$$

$$\varepsilon_{HDD} = \frac{HDD}{L_{HDD}} g'(HDD) \quad (6)$$

Previous studies have shown - that among all indicators of environmental conditions, including ¬ humidity, wind speed, air temperature, barometric pressure and etc., the air temperature can effect more in power consumption.

In order to calculate the temperature coefficient (TI) based on the location of weather stations, we should first calculate weight – population coefficient as shown in table 1.And then we calculate the sample amounts of TI for each station in July 1st and January 1st as shown in Table 2.

Table1. weight-population coefficient

Weather Station	City Name	Weight index($\mathcal{W}_i$)	Population
Egghlid	Eghlid	0.04	111377
Jahrom	Jahrom	0.077	211391
Shiraz	Shiraz	0.64	1749926
Firuzabad	Firuzabad	0.044	121775
Kazeroon	Kazeroon	0.101	278343
Lar	Lar	0.054	149097
Niriz	Niriz	0.41	112152

Table2.sample amount of TI in July and January 1st

City	Aug 1st 2009T_{ti}	Jan 1st 2009 T_{ti}	W_i	*Aug 1st 2009 TI_t*	*Jan 1st 2009TI_t*
Eghlid	28.8	7.5	0.04	1.152	0.3
Shiraz	36.5	14.3	0.64	23.36	9.15
Jahrom	39.7	17.7	0.077	3.05	1.36
Firoozabad	29.1	8.8	0.044	1.28	0.38
Kazeroon	35.3	15.3	0.101	3.56	1.54
Lar	41.9	20	0.054	2.26	1.08
Niriz	35.1	16.4	0.041	1.43	0.67
$TI_t = \sum_{i=1}^{7} T_{ti} W_i$	-	-	-	36.09	14.48

Results and Discussion

Analysis of the correlation between temperature and power consumption

In April and May we can see the rise of temperature. In early April the temperature is between 26-13 ° C and the mean temperature is equal to 19.5 ° C. temperate weather and New Year holidays are two main factors that we can't see considerable changes in network load variations. Correlation coefficient during this period (April and May) is 0.92. Since the middle of April and during May that the average air temperature increase from 19 ° C to 25 ° C, the network load, dependent on the air temperature and for each 6 degrees increase in the amount of TI the average network load increases around 207 MW during the years studied. Thus, changing in the level of air temperature from (13-27) to (17-30) is the reason of load dependence to environment temperature and cause a vivid increase on network load. During this period correlation coefficient between load and temperature is 0.88.

Table 3.Correlation coefficients during a year

County/ months	J	F	M	A	M	J	J	A	S	O	N	D
Eghlid	-.11	-.13	.12	0.84	0.86	.8	.85	.9	.84	.81	.8	-.4
Shiraz	-.1	-.11	.1	0.9	0.89	.71	.91	.94	.91	.78	.7	-.28
Jahrom	-.09	-.11	.1	0.92	0.91	0.7	.93	.94	.9	.76	.72	-.27
Firoozabad	-.1	-.1	.09	0.85	.84	.79	.9	.91	.86	.7	.78	-.33
Kazeroon	-.08	-.1	.07	0.91	.92	.71	.9	.95	.92	.77	.73	-.29
Lar	-.08	-.09	.08	0.97	.96	.69	.95	.98	.97	.89	.7	-.27
Niriz	-.1	-.12	.11	0.93	.91	.75	.92	.92	.92	.79	.76	-.26

This dependence between load and temperature undoubtedly is because of acting air conditions in hot air. During June, the average temperature will increase and this increasing network load level up to 1081 MW, that

is mostly cooling load. So the change in temperature from 19 degree to 25 degree make the network load becomes higher than previous levels and this over load is very remarkable.
Correlation coefficient of load and temperature during June is 0.72. During the months of July and August the average temperature has increased, but there hasn't been a significant increase in network load. The reason is, almost all of cooling devices are used before this period and increasing in air temperature in this level just increase the electric power of the device. Correlation coefficient during the months of July and August is 0.9 and 0.94 respectively.
During the months of September and October, the heating period is over and the average temperature is reduced. Correlation coefficient during the months of September and October is0.92 and 0.77.cold period of the year starts from early November. Changing in the level of temperature from 29° C to 15° C starts moderate weather conditions all over the province so the over load that caused by using electric cooling systems is reduced. Again Mild weather conditions reduced 390 MW of network load. Correlation coefficient is 0.72 during November. With the start of the cold period, during December, January and February, the network load starts to increase by the use of electric heating equipment. But this jump is not comparable with the increase in the hot period. The reason is using gas energy instead of electric power to make heat in houses. Statistics show an inversion on Dependence between the load and air temperature during this period so the correlation in December, January and February are -0.29, -0.09 and -0.1 respectively. During the month of November and December due to the moderate conditions, the load is less affected by temperature so correlation coefficient is reduced.

CDD HDD analysis
The basis temperature for calculating HDD is 15° C and it is 21° C for CDD calculations. But for Fars province basis temperatures for HDD and CDD are 17° C and 27° C respectively. The following maps show heating and cooling zoning in each season. It's done with GIS mapping system.

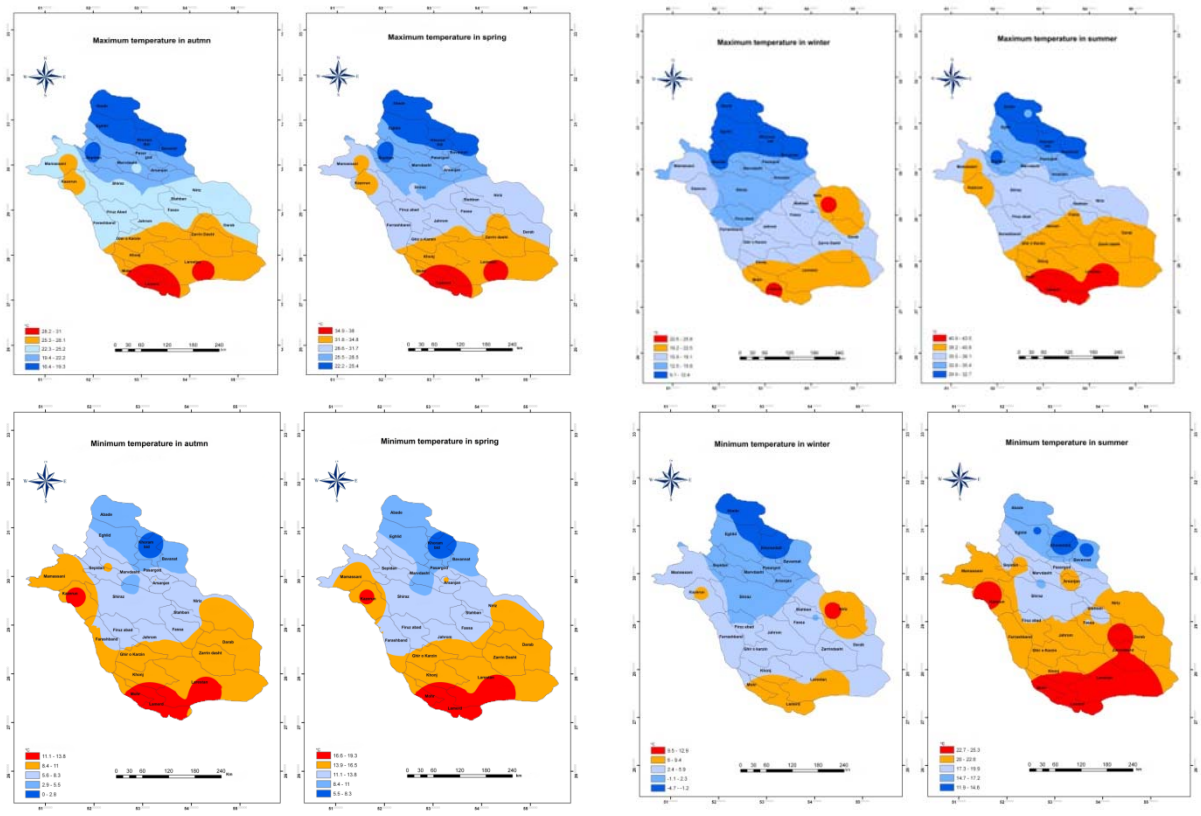

Fig2. Heat and cool zones of Fars in spring (top left), summer (top right), fall (down left)and winter(down right (2001-2010)

Coefficient of elasticity Times
Network's load variation curve in order to HDD and CDD functions is shown as$L_{CDD} = f(CDD)$and$L_{HDD} = g(HDD)$. Both functions are non-linear and show an upward trend to reach a peak. These upward changes,

particularly in cooling load function are very sharp. Elasticity coefficient demonstrates the sensitivity of the network load to temperature. The following graph represents the elasticity function for HDD and CDD in Fars power network during 2009.

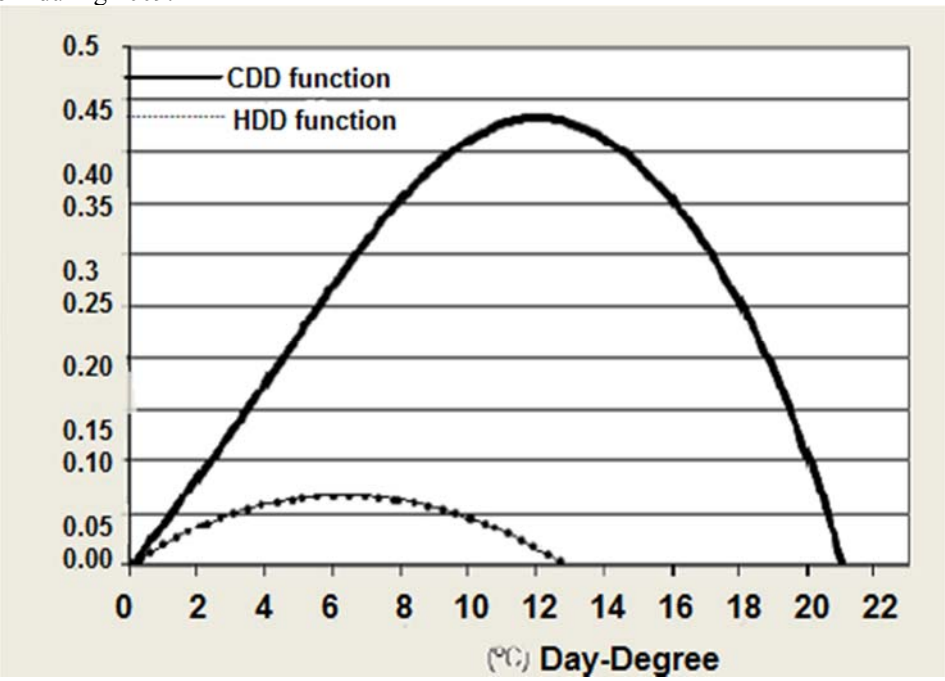

Fig3. CDD and HDD elasticity function

Elasticity values for CDD function are much larger than HDD. In other words, the sensitivity to changes in the network load in hot air is higher than the cold period of the year ¬. The highest elasticity is in 12 days - degree (CDD) and 7 heating degree days (HDD). The saturation point for CDD function is in 18 degree-days and 38° C and it is 7 degree-days and 9° C for HDD function.

Conclusions

In this study, we analyzed the effects of climate change (specifically temperature) on the electrical energy consumed in Fars province. Analyzing network's load trend and temperature variations shows a huge dependence between electric load and environmental conditions (particularly maximum air temperature). If we compare seasonal temperature variation with the correlation coefficients table, it confirms that these two are directly related. Also compare seasonal temperature changes with time and temperature correlation table confirms the two are directly related. Finally you can see consumed load variation that affected by air temperature as we simulated with GIS mapping system. As you can see these two maps are mostly join to each other. It means that the more increasing in temperature the more consuming in electric energy.

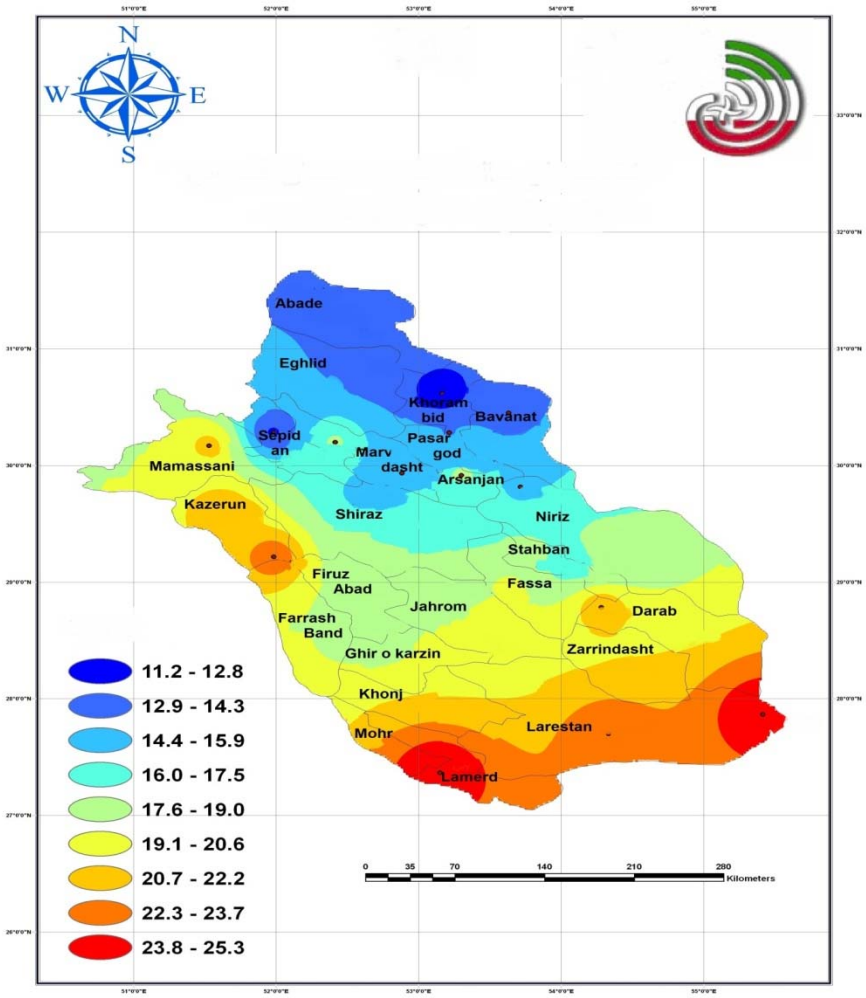

Fig4. Simulating thermal map for Fars(2001-2010)

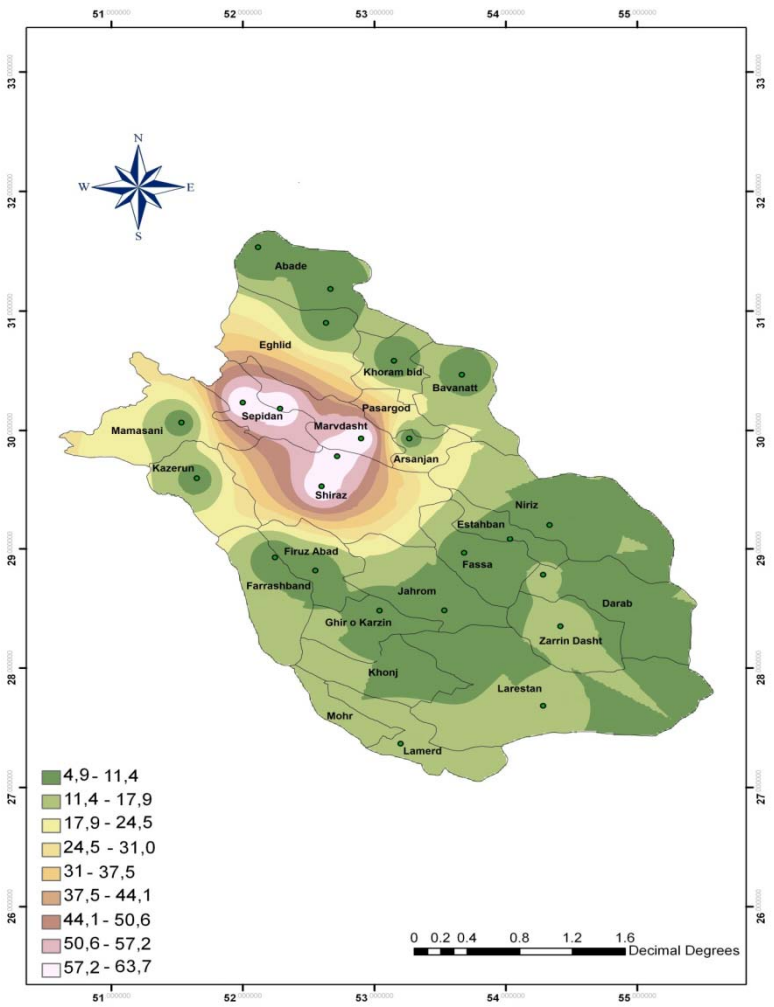

Fig5. Electricity consumption map (2001-2010)

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