THE REPUBLIC OF TURKEY
BAHÇEŞEHİR UNIVERSITY

# TURKEY'S SHORT TERM HOURLY ELECTRICITY DEMAND FORECASTING USINGARTIFICIAL NEURALNETWORK

M.S. Thesis

MUHAMMED G. YASIN

ISTANBUL 2013

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This is to certify that we have read this thesis and that we find it fully adequate in scope, quality and content, as a thesis for the degree of Master of Science.

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June 2013 Muhammed G. YASIN

# ABSTRACT

TURKEY'S SHORT TERM HOURLY ELECTRICITY DEMAND FORECASTING USING ARTIFICIAL NEURAL NETWORK

Muhammed G. Yasin

Computer Engineering Master Program

Supervisor: Asst. Prof Dr. Vehbi Çağrı Güngör

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The cost-based and the engineering calculation in pricing of electricity take place by the competition based on spot electric market. The price is determined by variety of market mechanisms. This led generators and all electric utilities such as traders face with a new problem in their scope of operation which is short-term load and price prediction. The purpose of this study is to indicate the importance of short-term load forecasting and how it has received a growing interest. After new legislation, competition based on hourly price in energy market has become the most valuable matter and forecasting of electricity load and price has become a big business. The total pool electricity or bus-load forecasting with engineering backgrounds is crucial to feed say statistical methods utilized for estimating the electricity price. The dynamic price in electricity market has led to the variability and non-stationarity of load. On the other hand, the number of nodes in which the load must be predicted is not constant and cannot be estimated by experts. In this competitive scenario forecasting methods should be more privileged. In this study, two different short-term strategies are used to estimate the hourly electricity load by an artificial neural network. The main objective is to find the most powerful method that predicts the hourly load and to develop more accurate load forecasters. The hourly temperature data combined with the time series have been used throughout this study to test the proposed methodology.

**Key Words:** Short Term Forecasting, Artificial Neural Network, Load Forecasting

# ÖZET

YAPAY SİNİR AĞI İLE TÜRKİYE'NİN KISA VADELİ SAATLİK ELEKTRİK TALEP TAHMİN

Muhammed G. Yasin

BigisayarMühendisliğiYüksekLisansProgramı

Danışman: Yrd.Doç. Dr. ÇağırıGüngör

Haziran 2013, buçalışma 52sayfadanoluşmaktadır

Rekabetin gelişiyle, saatlik elektrik fiyatı üretim maliyeti ve mühendislik işletiminden ziyade, elektrik piyasası işleyişi ile değişim göstermeye başladı. Bunun sonucunda elektrik üreticiler ve ticari firmalar yük tahmini ve fiyat tahmini problemiyle karşı karşıya kalmaktalar. Bu çalışmanın amacı kısa dönem yük tahmininin önemini ve bu önemin son zamandaki artışını ortaya koymaktır. Yeni mevzuat çıkışından sonra, enerji piyasasındaki fiyat rekabetinin saatlik yapılması son derece önem kazandı, enerji fiyat öngörüsü büyük bir işe dönüştü. Bulanık mantık yöntemleriyle elektrik fiyatı tahmin edebilmek için hat yükü veya havuzdaki enerji miktarının öngörüsü, temel gereksinimlerden biri haline gelmiştir. Elektrik fiyatının değişkenliği, durağan olmayan bir yükü beraberinde getirmektedir Öte yandan, tahmin edilmesi gereken düğüm yükü sayısı uzmanlar tarafından sürekli tahmin edilememektedir. Daha fazla ayrıcalıklı öngörü yöntemleri bu rekabetçi senaryoya gerekmektedir. Bu çalışmada iki farklı strateji ile kısa dönem saatlik elektrik yükünü tahmin edebilmek için yapay sinir ağı kullanılmaktadır. Buradaki temel amaç en güçlü tahmin yöntemini bulabilmektir. Bu amaç için geçmişe yönelik saatlik yük ve şehir sıcaklıkları kullanılmaktadır.

**AnahtarKelimeler:** Kısa Vade Tahmin, YapaySinirAğı, YükTahmini

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| | |
|---|---|
| STLF | Short-Term Load Forecasting |
| MAED | Model for Analysis of Energy Demand |
| STLF | Short-Term Load Forecasting |
| EU | European Union |
| MENR | Ministry of Electric and Nature Resources |
| EMRA | Energy Market Regulatory Authority |
| IAEA | International Atomic Energy Agency |
| MFSC | Market financial settlement center |
| SPO | State Planning Organization |
| MAPE | Mean Absolute Percentage Error |
| MAE | Mean Absolute Error |
| LM | Levenberg–Marquardt Algorithm |
| TEK | Turkish Electricity Institution |
| TETAS | Turkish Electricity Trading and Contracting Company |
| TEIAŞ | Turkish Electricity Company |
| EUAŞ | Electricity Generation Company |
| TEDAŞ | Turkish Electricity Distribution Company |
| CAGR | Compound Annual Growth Rate |
| ENTSO-E | European Network of Transmission System Operators for Electricity |
| GDP | gross domestic product |
| ANN | Artificial Neural Network |
| GA | Genetic Algorithm |
| GPRM | Grey Prediction with Rolling Mechanism |
| PSO | Particle Swarm Optimization |

| | |
|---|---|
| PSOEDF | Particle Swarm Optimization based Energy Demand Forecasting |
| ACO | Ant Colony Optimization |
| HAP | Hybrid approach Based on Particle |
| HAPEL | Linear HAP |
| HAPEQ | Quadratic HAP |
| SARIMA | Seasonal Autoregressive Integrated Moving Average |
| AR | Autoregressive |
| ARIMA | Autoregressive Integrated Moving Average |
| UC | Unit Commitment |
| DSI | State of Hydraulics of Turkey |
| MTA | Mineral Research and Exploration |

# 1. INTRODUCTION

In general description, need and necessity of electric market is handled. Electric energy history and electric market formation and its importance for development of capacity are introduced in this section.

## 1.1 GENERAL DESCRIPITION

One of the most important factors to improve the quality of life is energy, it also ensures the economic and social development. However, raising energy prices, climate change and global warming has led to an increase in energy demand throughout the world. On the other side the rapid consumption of fossil fuel and being dependent on it, as well as the insufficiency investment for developing new technologies, to meet the growing demand for commercial energy, makes countries worry about the security of energy supply.

## 1.2 ELECTRIC ENERGY

The first use of electricity in the world in daily life was in 1878. The first power plant was put into service in 1882 in London. During the seventeenth and eighteenth centuries the electricity had a direct effect on transforming industry and society.

## 1.3 MARKET FORMATION PROCESSES

Our country's first power plant is in Tarsus, which was established in 1902, with a power of 2 kW dynamos connected to a water mill. The first major power plant was established in 1913 in Istanbul Silahtarağa with a power of 17 MW. By law: 2805, under the government agencies in 1935 Etiban cooperation was established, and the government itself began to operate the power plants. By this alteration and the support obtained from General Directorate of Mineral Research and Exploration (MTA), Iller Bank and State of Hydraulics of Turkey (DSI) managed to connect an abundant quantity of country’s thermal and hydroelectricity plants to electricity network.

In 1923, population in Turkey was 12 million and yearly consumption was 3.6 kWh per capita. This amount was expected to increase 758 times to (2,728.5 kWh/capita) at the end of 2008, where the population projection was 74.8 million.

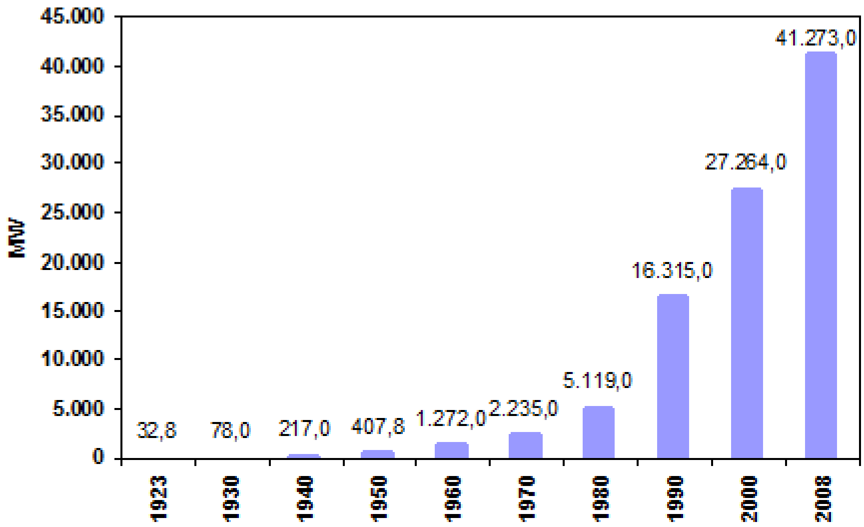


**Figure 1.1: Turkey total installed power**

From 1923, when Turkish Republic was founded, to 2008 the installed power increased nearly 1258 times (from 33 MW to 41,273 MW). In 2009, 3000MW with 2800MW private capacity has been added to system, and in 2010, 1500MW private installed capacity has been added. By the end of 2012 the total installed capacity has increased to 57,058 MW

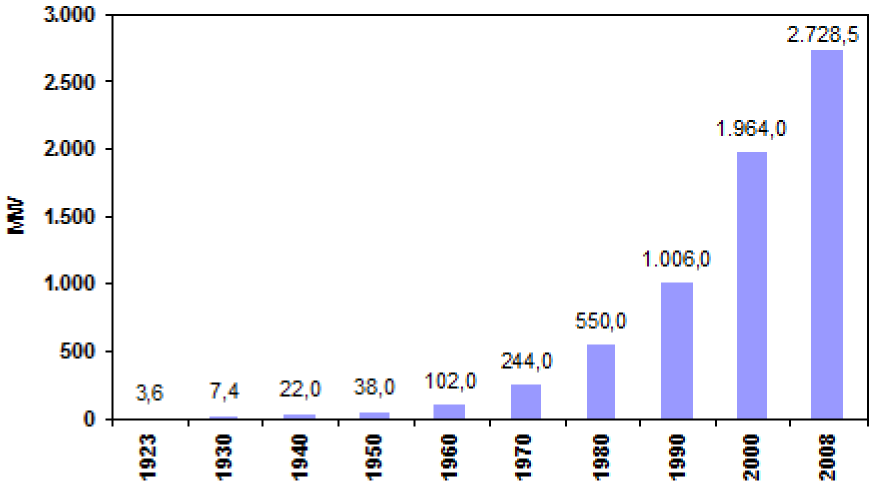


**Figure 1.2: Yearly consumption per capita**

Turkish Electricity Sector has undergone physical and structural changes since 1923, when the Turkish republic was founded. In 1994, Turkish Electricity Institution (TEK) was separated into twoindependent state economic enterprises, Turkish Electricity Company (TEAŞ) and Turkish Electricity Distribution Company (TEDAS).

In 2001, Electricity Market Law (number 4628) was published in the official gazette and studies on establishment a competitive and free market have been initiated. With this law, TEAŞ has been restructured as Electricity Generation Company (EUAŞ), Turkish Electricity Transmission Company (TEIAŞ) and Turkish Electricity Trading and Contracting Company (TETAŞ).

With the Electricity Market Law:

a. Generation, transmission and distribution activities has been separated
b. Wholesale and retail sales activities started
c. Bothparticipants (the private and public sector) fairly benefited from distribution and transmission lines.
d. Separate licenses are issued for each activity (distribution, retail, wholesale, generation etc.)
e. Imbalances, that cannot be met by short-term bilateral agreements, are started to be settled by Market Financial Settlement Center

Turkish Electricity System is operated by the National Load Dispatch Centre (NLDC) located in Ankara-Gölbaşi, together with 9 regional control centers located in: Istanbul, Ankara, Izmir, Adapazar, Samsun, Keban, Adana, Erzurum and Antalya.

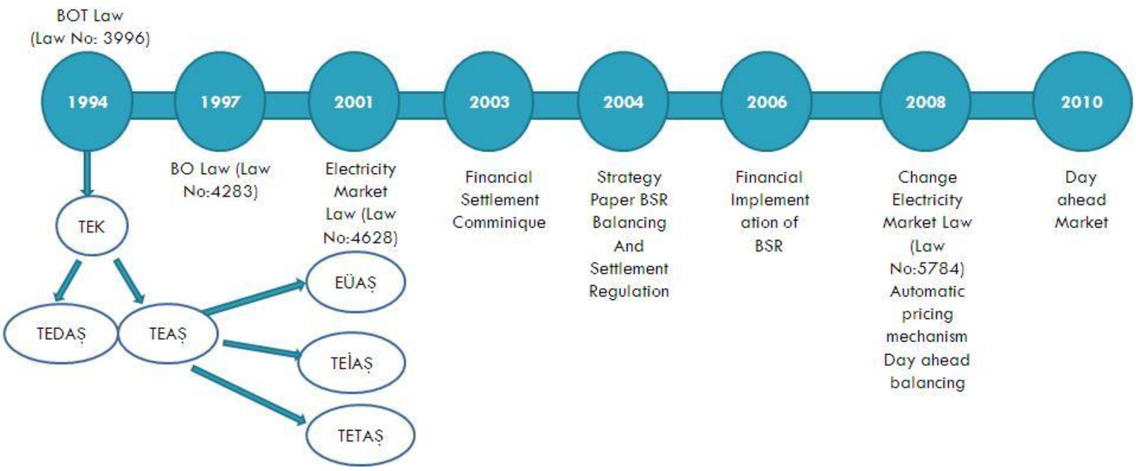


**Figure 1.1: Electricity sector reform milestones**

The need for risk management applications and newly emerging human resources profile brought by the developing trade environment which caused by new legislation infrastructure developing in alignment with the new sophisticated requirements.

With the privatization of the power distribution and generation, structure of the sector has changed significantly. Especially with privatization of the distribution, a new business model hasarisen, electricity trade has been elevated to a more competitive level with the onset of a day ahead Planning and Power Market of which regulated by final balancing and settlement legislation. Furthermore, trade competency and risk management ability have gained significance, especially for the suppliers.

With aforementioned changes in legislation of market liberalization, the appearance of Turkish electricity energy sector has been progressed and changed significantly. The level of competition has increased, more and more players have entered the market every day. The new regulations regarding the market structure and trading, the decrease of public share due to privatization in electric distribution and generation, and the fierce competition due to increased investments have relevantly increased the necessity of market players to develop new competencies and structure.

The first organized electricity market started its operations with the balancing market becoming operational.

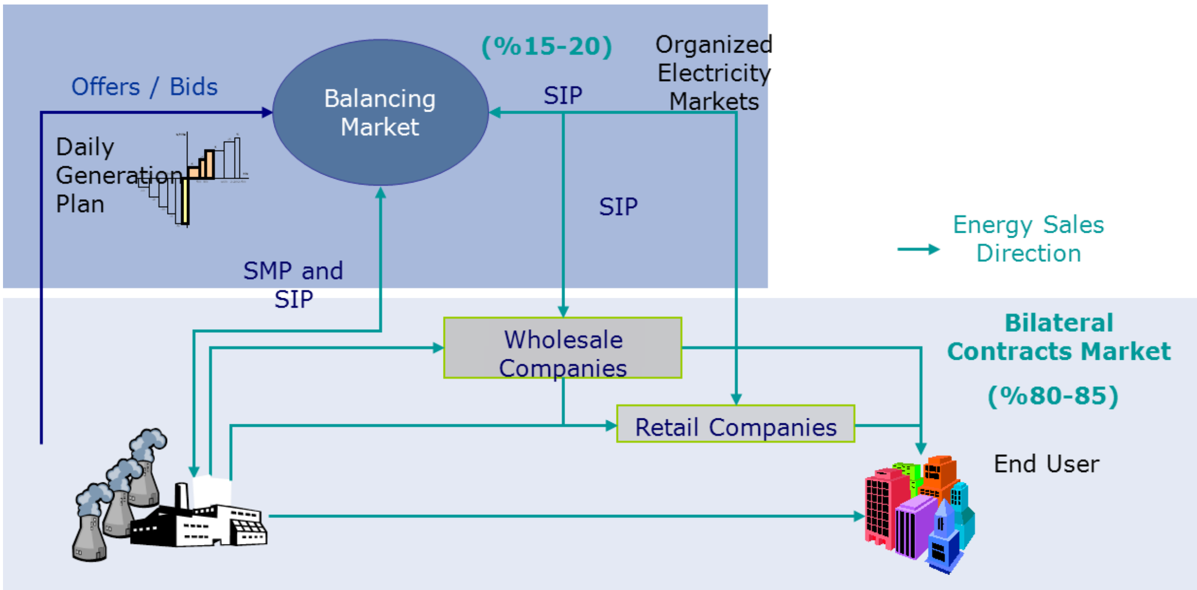


**Figure 1.2: Turkey electric market process**

All the generators that are above a certain generation capacity submit their daily generation schedules and bids/offers to increase or decrease their generation with respect to the Daily Generation Schedule submitted to (NLDC), on a daily basis. The System Operator balances activities by considering these bids/offers.

In competitive electricity markets, in order to find the market-clearing price, the system meets all the demand of the market and the last offer of generation unit hours will be the market clearing price for that hour. In a fully and well operated and established competitive market, the market marginal price must be same to the marginal cost of the last electric supplier. But the current condition of competition in electricity markets is far from meeting the full competition. This reflects the fact that there are a restricted number of electricity generators, and according to customer demand, the market price is extremely inflexible, especially in periods of high demand, there is considerable room for exercise of market power.

## 1.4 THENEED FOR THE NEW MARKET

In the new business model covering electricity demand and price forecasts, hydro thermal generation scheduling, pricing and trading processes, management has come into question. Thus the necessity of competent human resources has increased, wherenot only capability and vision in technical andin engineering fields but also in law, economics and financial background are required.

Changing market structure creates many different risks. Furthermore, it mandates the incorporation of effective risk management processes, ranging from the development of institutional risk management strategies to identification of operational risk control points.

All the mentioned above could be consolidate under three topics; demand, development and expectations. The second could exist in investment environment development and expectations for supply development, and the last one is the business processes.

### 1.4.1 Demanddevelopment

Within the demand development the demand forecast is essence of decision making processes in market activities, the long term demand is basically affected by economic growth, increase of population and urbanization, these are main factors for demand.

Although Turkey's electricity demand forecast should be based on the cumulative demand forecast of each region distribution company by virtue of Electric Market Grid Regulation and Regulation Concerning Electricity Demand Forecast, currently it is still calculated by Ministry of Energy and Natural Resources by using MAED (Model and Analysis of Energy Demand). According to the latest "Turkish Electrical Energy 10-YEAR generation Capacity Projection (2009-2018) Report" published by TEIAŞ, public electric demand is expected to reach 336TWh with 6.3 percent compound annual growth rate (CAGR) in base scenario in 2018 and 357TWh with 7 percent CAGR in high scenario.

While the economic crisis has a mitigating effect on possible supply security problems, it also provides opportunities; to improve the investment environment in short, medium, and long terms and to speed up the preparations and applications that will enable a well prepared, well-functioning and competitive electricity market. With the decreasing impacts of the economic crisis in the last months of 2009 and in the first quarter of

2010, electricity demand, again, started to display an increasing trend which increases the likelihood of supply security issues to be repeated in the medium term.

The gross domestic product (GDP) and the electricity consumption per capita show nearly a linear relationship for Turkey starting from 1980 and it is an indicator of development for medium and long term. While GDP was 2,100 USD/capita and the electricity consumption per capita was 750 kWh/capita in 1980s, both was doubled in 1990s and GDP reached 6,350 USD/capita on average, and electricity consumption per capita reached 2,300 kWh/capita in 2000s. After the economic crisis, whose effects are gradually decreasing, the economic growth regained acceleration. Due to accelerated economic growth and increasing population and urbanization, expectations for consumption per capita and GDP per capita, which show an increasing pattern, indicate that there is a huge potential for electricity demand growth. In other words, it could be predicted that the electricity demand will increase exponentially in medium and long term once the crisis and the electricity consumption per capita has shown a parallel increase with GDP.

ENTSO-E (European Network of Transmission System Operators for Electricity) is one of the world's biggest synchronous systems that cover most part of Europe. Turkey has a top priority target of synchronous connection with ENTSO-E network, which is important in terms of Turkey's relation with Balkans and South-East Europe. Substantial improvements in the quality of the system frequency have been achieved to enable this synchronous connection, thus the expectation of the establishment of such connection in the near future will provide a pertinent increase.

When Turkey and the ENTSO-E member countries are compared with respect to the anticipated demand growth rates in 2010-2020, it is clear that Turkey has a relative high growth potential. Especially when neighboring countries which are expected to have high growth rates are considered, it could be seen that Turkey might not only meet its own demand but also could exploit the opportunity to make cross-border electricity trade in the subsequent years. Moreover, countries which have aggressive targets regarding clean energy in their current agenda would provide trading opportunities for electricity generated from renewable resources, which would have a positive impact on renewable energy investments in Turkey.

### 1.4.2 Supplydevelopment

Up to now, we have discussed the development of demand and its essence in energy market. It is also important to take the supply, and the role and essence of the supply in energy market. If we look over Turkish electricity sector for three different eras; TEK period, period of unbundling of generation, transmission, wholesale and distribution or retail sales operations and the period of market structuring, we see that investment with different volumes and technologies have been realized to meet the increasing demand.

When the installed capacity in Turkey is examined, it is observed that starting from 1985 on average 1.463MW new installed capacity is added to the total installed capacity annually. Based on technologies of new investments, it is seen that years between 1987 and 1993 can be categorized as "era of hydroelectric investment" while from 1998 till 2005 can be categorized as "era of natural gas investment".

Recently in Turkey, electricity generation from renewable resources attracts intense attention, especially that investments for a wind and small hydroelectric power plants are in a rapid increase. Examining the installed capacity based on the ownership structure, it is seen that during the period 1984-2009, the public share has decreased significantly. Public share EUAŞ fell from 85 percent in 1984 to 52 percent in 2009. It is expected that the public share will continue to decrease with privatizations of EUAŞ power plant that started in 2010, as well as with new private sector investments for meeting the increasing demand. By the increasing share of private sector, it is expected that the positive improvement will be attained to create competitive electricity market.

### 1.4.3 Supply – Demandbalance

While electricity demand and supply have meticulously developed within last decade, on behalf of business process Turkish government with Ministry of Electric and Nature Resources published several regulations to protect retail users and security of supplier. All these have been done by new legislation for balancing and operation transparencies. Theoretical reserve capacity (the installed capacity percentage remained at peak load), a significant indicator of the supply-demand balance shows a fluctuating pattern depending on the supply-demand balance development and it gradually decreased in the period 2003-2008, when the demand was steadily increasing.

## 1.5 CAPACITY AND INVESTMENT NEEDS

Total installed capacity projected for 2018 mentioned in the 2009-2018 capacity projection study published by TEIAŞ in June 2009, (two scenarios and total installed capacity of 44,559 MW in 2009 are considered) reveals that newly licensed capacity and capacity in construction are expected to reach 11,823 MW in Scenario 1 and 9,681 MW in Scenario 2. In the 2009-2018 Capacity Projection Report, peak demand is forecasted to reach 55,053 MW and 51,757 MW according to high and low demand scenarios, respectively. Within this scope, when capacity requirements are considered by taking into account primary, secondary, tertiary and other system operation reserves as 25 percent, it can be seen that 68,816 MW of capacity requirement for 2018 emerges. When total installed capacity for 2018 (current and in construction) is taken into consideration, for Scenario 1; 12,434 MW, for Scenario 2; 14,576 MW additional capacity requirement is predicted until 2018.

It should be noted that reduction in available capacity, which occurs especially due to the aging problem of publicly owned thermal power plants, has not been reflected in this study. However, aging capacity could be neglected due to upcoming privatizations that would call for the new owners of privatized plants to invest in plant rehabilitation and capacity increase.

Timely commissioning of new capacity depends on some critical factors such as;

a. establishment of a well-designed, well-functioning and competitive electricity market,
b. measures taken for security of supply to ensure the availability of predictable sales opportunities or incentives that would provide return of investments,
c. providing predictability, transparency and a confident environment as per the economic, political and regulatory framework,

d. access to resources such as machinery/equipment, infrastructure, qualified work force,
e. access to effective financial resources.

Since 2006, when the electricity market has become operational and the price has started to be determined liberally, investors have developed confidence towards the competitive market and market price came up to levels that encourage investments. Power plants which have cost advantage in generation are clearly in an advantageous position in the market.

Considering the capacity that can be attained in 10 years, disregarding the unutilized economic potential of domestic resources, fuel and infrastructure constraints for imported resources, it is obvious that energy efficiency is the ultimate source of energy in the coming years, in terms of both security of supply and contribution to conservation of the environment. Although the impact of solar and wind technologies on the environment are low; due to their limited contribution to supply security, those technologies should be utilized within their technical and economic potential, and additional security of supply measures should be taken.

**Table 1.1: Detailed table shows the installed capacity for years 2012 and 2013**

| Institution | 2012 | | | 2013 | | |
|---|---|---|---|---|---|---|
| | Installed capacity (MW) | Contribution % | Number of generation unit | Installed capacity (MW) | Contribution % | Number of generation unit |
| EUAŞ | 20904.8 | 36.6 | 97 | 20889.5 | 36 | 94 |
| EUAŞ Partners | 3870 | 6.8 | 5 | 3870 | 6.7 | 5 |
| Delivered generators | 875.2 | 1.5 | 38 | 904 | 1.6 | 41 |

| | | | | | | |
|---|---|---|---|---|---|---|
| B.O. Generators | 6101.8 | 10.7 | 5 | 6101.8 | 10.5 | 5 |
| B.O.T. Generators | 2419.8 | 4.2 | 21 | 2419.8 | 4.2 | 21 |
| Private Generators | 19685.9 | 34.5 | 427 | 20537 | 35.4 | 459 |
| Self-producer Generator | 3200.8 | 5.6 | 178 | 3320.3 | 5.7 | 186 |
| TOTAL | 57058.4 | 100 | 771 | 58042.5 | 100 | 811 |

# 2. LITERATURE REVIEW

Current situation and the future of investment are introduced in this section. Also, relevant researches done in different fields within the scope of load forecasting approach are ordered.

## 2.1 INVESTMENT AND DEVELOPMENT

Currently, Turkey's energy demand is growing faster than energy production. Respectively, the total energy consumption in 2010 and 2020 is predicted to be 126.3 and 222.4 Mtoe on the other hand the production is estimated to be 37.5 and 66.1 Mtoe of domestic energy production according to Turkey's Electricity Generation Inc. (EUAŞ). As this is the case, the total consumption of electric energy within the final energy has been increasing. 7.9 percentage of increase happened in 2007, it has reached to 184.4 TWh. At the same year the (GEG) reached to 191 TWh with increase of 8.7 percent. According to high and low scenario, Guler (2008) pointed to electric demand of Turkey and he predicted it to reach 440.1 and 483.6 TWh by the year 2020. He, in his reports demonstrated that current installed capacity should be doubled to meet the increasing electricity demand, he also pointed to the amount, whether the capacity should reach to 80,000MW and increase to 96,000MW by the year 2020 according to both scenarios. As this is a case, the investments have been initiated, the total installed capacity of 12,600 MW, which includes 1000 MW wind and other renewable, 8100 MW hydraulic and 3500 MW thermal which the expectation is to be completed by the end year 2013.

Turkish electricity market shows a dynamic structure in which new investments come into agenda each day due to demand increase, triggered by the economic growth and the increase in population, along with a competitive environment that has been developed with the deregulation. This, in order to meet the investment needs in a healthy way and to provide security of supply, along with establishing an efficient market structure that provides true price signals, a reliable and effective legal infrastructure for the future of the sector.

And it is observed that the market has been changing significantly along with the latest developments thus; players, necessities and conditions of competition have been experiencing a rapid change.

## 2.2 STRUCTURE OF SECTOR AND DEVELOPMENT OF REGULATION

Turkish electricity market reform of the last 20 years aims to increase productivity, ensures security of supply through market mechanism and secures customers' freedom of choice. Within this scope; legislation and organizational issues shall be resolved as a priority.

Design of new structure and development of the regulations for a competitive, well organized and effectively functioning electricity market, preconditions can be listed as follows:

a. Legal infrastructure
b. Autonomous regulatory body
c. Unbundling of activities and accounts
d. Independent transmission system operator
e. Independent market operator

Regulation infrastructure, including basic rules such as; qualifying conditions for being a market participant (license, etc.), network access and cost based tariffs, is the keystone of a liberal market.

It is essential for establishment of a reliable market that those rules, with equal treatment of equal parties, should be regulated and supervised by an autonomous body independent of political authority. With the Electricity Market Law No: 4628, which came into force by March 03, 2001, the first steps have been taken for creating a reliable energy sector having the attributes presented above, and for conformance to the European Union acquis and energy regulations. Although significant structural and legal changes that have been envisaged by the law were completed in the last 10 years, it should still be kept in mind that setting up a well-organized and efficient market, and ensuring competition in the electricity sector is a long term process. In this process; experienced failures in practice, deficiencies and difficulties that affect market development should be eliminated, investment environment under changing market conditions should be improved, and roles and responsibilities of related parties shall be clearly stated by implementing timely and necessary legislative changes.

Within the scope of electricity market reform, that has been accelerated with the Electricity Market Law No 4628 enacted in 2001; considerable progress regarding legislations and privatization have been made.

a. Transition to day-ahead planning and balancing power market which is based on hourly settlement arranged with the Final Balancing and Settlement Regulation in 2009,
b. And introduction of Primary Frequency Control in 2009 and Secondary Frequency Control in 2010 in accordance with the Ancillary Services Regulation,
c. Replace day-ahead planning with day-ahead spot market in 2010,

are the most important developments regarding the structure of the sector recently.

The main legislative changes in electricity market reforms could be summarized as below:

i. Law No. 4628 (2001): the market development phase, BSR and Bilateral Contracts, MFSC, Auto producer market sales cannot exceed 20 percent of its generation, Eligible customers First eligibility limit: 9 GWh/year
ii. Law No. 4628 (2001): Ensuring security and supply , TEIAS prepares "Generation Capacity Projection and submits to Board's approval, EUAS can commission, rent and operate new generation plants, when necessary
iii. Law No. 4628 (2001): Vertical Integration (Generation and Distribution/Retail), At most 20 percent of total energy distributed can be supplied from own generation company
iv. Law No. 4628 (2001): Transition Period and Vesting Contracts (VC), Preparation Period 18+6 months

v. Law No.5398 (2006): Vertical Integration (Generation and Distribution/Retail), 100 percent free provided that the accounts are separate, Industrial zones can involve in distribution and/or generation activities

vi. Law No.5398 (2006): Privatization and Investments and Ownership After Privatization, investments made after privatization are owned by public, If investments are not made then license is cancelled anda new tender is done.

vii. Law No. 5496 (2006): Transition Period and Vesting Contracts (VC), December 31, 2010 Maximum 5 years VC -TETAS-EUAS-Distribution companies -Public generation companies and new groups formed by restructuring of EUAS

viii. Law No. 5627 (2007): Guarantee, Sanctions and Penalties, authority requires guarantee for current generation licenses and license applicators

ix. Law No. 5784 (2008): The Market Development, Ancillary Services Regulation-Capacity Mechanisms

x. Law No. 5784 (2008): Ensuring security and supply, roles and responsibilities are defined , supply security monitoring and evaluation process is completed

xi. Law No. 5784 (2008): Guarantee, Sanctions and Penalties, license belong to a legal entity, who could not realize its generation plants investment within the specified period declared in legislations, will be cancelled, it cannot make license application for 3 years. It cannot have a share directly or indirectly in another legal entity's application.

xii. Law No. 5784 (2008): Privatization and Investments and Ownership After Privatization, Even if EUAS assets are taken under privatization, still they are managed by the Ministry and EUAS-Revenues obtained from privatization of EUAS assets are used for sector investments

With the enhancement to Electricity Market Law (Law No: 5784, The Amending Law) enacted on July 26, 2008 and due to delays in privations, the transition period has been extended to December 31, 2012. This law also includes legal arrangements regarding monitoring the security of supply and taking necessary precautions, together with incentives for new investments and arrangements regarding the elimination of problems occurred during the construction phase.

## 2.3 INVESTMENT ENVIRONMENT AND OF ELECTRICITY MARKET

Turkish energy policy aims to provide electricity energy in an affordable, high quality, uninterrupted and environment-friendly way; securing a balance built on three piers of competition, security of supply and environment-consciousness in compliance with the EU policy. Competition, security of supply and protecting the environment might sometimes conflict with each other and their priorities might change from time to time.
Here, for the development of the market, establishment of a well-organized and efficient electricity market structure that ensures competition by placing the consumer’s freedom of choosing the supplier at the center, increasing the interconnection capacity between neighboring countries, removing the obstacles to competition and ensuring third party access to system are crucial factors. In this respect, market regulations should be made to encourage new generation and system investments and to consider the environmental dimension, at the same time.

Establishment of a well-functioning free electricity market with reliable and transparent information and an effective price mechanism will enable the commissioning of the required investments by providing competency in foreseeing risk and return. It is essential to ensure attractive conditions for local or foreign credit institutions, in order for the necessary investments to be completed on time.

It is essential for the economy and modern society that electric energy is supplied continuously with a descent price. Transition to a competitive market does not mean that everything about the price and customer services are left to the free market, or displaying a laissez-faire approach. It is very important here to secure the balance between regulation and the free market. In a competitive market, where the government’s role is restricted solely to regulation and monitoring, it is crucial for the government not to interfere with the free market's functioning as much as possible and to define clearly the situations, conditions and timing of the market interference in terms of reassuring the market and maintaining transparency.

Consumers and politicians require low prices, but in case low prices are not appealing for the investors, low price levels should not be preferred for the sake of security of supply. For the investors; high prices are more attractive however; it is not preferred by consumers and politicians. The balance here will be reached by the dynamic price reflecting the supply-demand balance. When supply is insufficient, prices increase and send signals to investors for further investment. If the supply is at an adequate level, as a result of new capacity investments or demand management; the price decreases and consumers benefit from this.

In case of recurrent supply insufficiency as a result of demand increase, new supply investments or demand management help to decrease prices. This mechanism, being predictable and able to reflect the price dynamics, reveals a structure that provides an opportunity for taking necessary precautions.

The most important fact here is that consumer side plays an active role in determining the price, and therefore providing the price flexibility. Second important subject is the late respond of supply to demand due to investment duration for providing simultaneous demand and supply increase.

Excess capacity investments are generally made according to the projections made by monopolies subject to regulation, however investors in the competitive market take the electricity market price as a “signal’’ so they invest according to the long term expectations. Companies with a large end consumer portfolio will make their investments in order not to get exposed to a volatile spot market price. In a competitive market; everyone has a right to make new generation investments. Large scale consumers may construct new generation facilities by taking into account their investment and main fuel costs and comparing electricity market price and their generation costs.

Analyzing the generation licenses granted by EMRA between 2005 and the first quarter of 2010, it can be observed that the new cumulative generation licenses which was 5,319 MW until August 01, 2006 -when the balancing market became operational- has grown 7 times by April 2010 and reached 36,023 MW. In other words, it can be observed that the electricity market incorporating the market price mechanism, which essentially is reflecting the short term supply-demand balance and is based on bids/offers of market participants for increasing or decreasing their generation, is considered by investors and market participants as an important step for establishing a healthy pricing mechanism and is taken into account for their investment decisions.

## 2.4 ELECTRIC PRICE MECHANISMS

The main feature of a well-organized, competitive and efficient electricity market is a reliable, transparent energy price that reflects the cost and provides signals for the investors. Price mechanism is supposed to be free from any intervention and be able to reflect the true supply-demand balance.

In a well-functioning market, decisions of investors depend on economic incentives and signals. Price of electricity contains those signals and the reliability of price is crucial for the market. In advanced markets, price reflects the willingness of selling for the producer and willingness of buying or reducing consumption for the consumer. In any case in the market, supply and demand balance determines the market price. In the market, price of power is set at the intersection point of supply and demand curves. Supply curve is the short run marginal cost curve for power generation, which is also known as the merit order. Market price equals to the short run marginal cost of the last KWh of energy that is required for meeting the demand.

Short-run marginal cost is the variable cost that consists of fuel cost and variable operating cost. Here it should be noted that fixed costs that include operating and maintenance costs are neglected.

Long -run marginal cost is composed of short run marginal costs and fixed costs. Long run marginal cost plays an important role in investment decisions and investments made by considering the long run marginal costs forms the short run marginal cost curve in the market.

The market price (corresponding to the short run marginal cost of the last operating power plant) is set at the intersection point of demand and supply curves and it may be possible that for some period of time the market price be set at a level lower than the long run marginal costs.

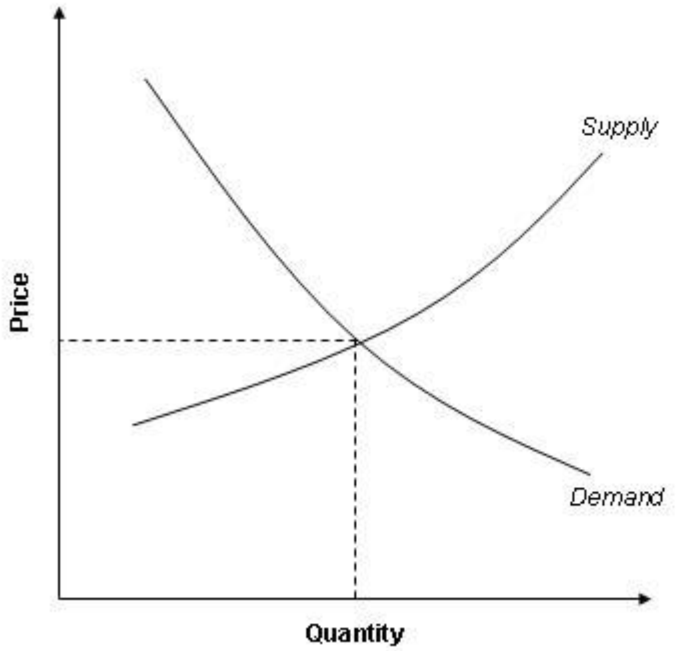


**Figure 2.1: Electric supply demand curve**

Investors tend to minimize the marginal cost of short run electricity supply by building more efficient power plants and in consequence they can have lower operation cost as comparing to the same resource type competitors. To attain these goals, investors apply efficient program management in the whole process.

For efficient program management, power suppliers tend to forecast pool load to schedule the generation hours and to decide on its bid strategy whether in a day ahead or power market.

## 2.5 RECENT STUDIES OF PROJECT

Since energy forecast and modeling is common current topics in which peoples in industry and lots of academicians have dealt with issues of electricity energy generation and consumption, lots of research and article has been written on forecasting electric demand. We try to focus on some of them:

M. S.Kıran, E.Özceylan, M.Gündüz and T.Paksoy(May 2011)for forecasting electricity energy demand of Turkey they had developed a based on Particle Swarm Optimization with novel hybrid approach and Ant Colony Algorithm. For prediction of electric energy demand of Turkey they used Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) with a new hybrid method (HAP) proposition. They have developed HAPE in two forms; linear (HAPEL) and quadratic (HAPEQ). They also used different scenarios for estimating the future energy demand. They have made a comparison with ACO and PSO for test the accuracy of their algorithm. Their result showed that lowest relative estimation errors obtained from the HAPE model whereas the quadratic form (HAPEQ) provides better-fit solutions, this because of the fluctuations of the socio-economic indicators.

E.Erdogdu(April 2006) used cointegration and ARIMA modeling for electricity demand analysis. He used both of them for estimating the electricity demand. He hadused the official projections for comparing results. In his conclusion he demonstrated that the respond to price changes is quite limited by the consumers'which it means that the need for economic regulation in Turkish electricity market is highly important, and the second conclusion is overestimate have done by the current official electricity demand projections.

C.Hamzaçebi (August 2006)He performed artificial neural network (ANN) forpredict data until 2020 of net electricity energy consumption of Turkey which based on sectoral. He compared official forecasts with once he foundedby ANN.

M.Kankal, A. Akpınar, M. İ.Kömürcü and T. Ş.Özşahin (May 2010) had used socio economic and demographic variables of Turkey for modeling and forecasting consumption of energy. In their study they dealt with the energy consumption and its modeling of main land Turkey, they used artificial neural network (ANN) and regression analyses for forecasting Turkey future projections which based on socio-economic and demographic variables. They have used gross domestic product-GDP, population, import and export amounts, and employmentas a demographic variables in their study.They have found that the proposed model resultaccuracy is higher than the regressionmodels and the ANN models. All the ANN forecasting results had been compared with the official forecasts and it was analyzed that the MENR gave higher estimates of the energy consumption than ANN and also it showed that the future energy consumption of Turkey would vary between 117.0 and 175.4 Mtoe in 2014.

A. K. Topalli, İ.Erkmen, İ.Topalli(July 2004) on behalf of Beko Electronics Co with Department of Electrical and Electronics Engineering of Middle East Technical University had developed intelligent for short-run load forecasting in Turkey. They have developed methods for forecastingtotal electric load in one day ahead of mainland Turkey. They implemented their algorithm byusing recurrent neural networks, theaccuracy result after using data from 2002 obtained as 1.60 percent.

B. Akdemir, N. Çetinkaya (December 2011) had developed an adaptive neural fuzzy inference system for forecasting long-term load in whichthey used real energy data. The total accuracy result of data from 2003 to 2025 was 0.82439 percent according to the mean absolute percentage error.

G.Oğcu, O. F. Demirel, S.Zaim had developed Neural Networks and Support Vector Regression for forecasting Turkey's electricity consumption. They like others have used MAPE as accuracy metric. The test results of two years period of 2010-2011 showed 3.9 percent in ANN and 3.3 percent in SVR.

M.Tunc, Ü.Çamdali and C.Parmaksizoğlu had made a comparison between Turkey and some European country in term of electrical energy consumption and production and also they made an optimization on the future electrical power supply investments. In their study they have compared between Turkey and France, Germany and Switzerland in term of installed electric power capacity and the resources of energy as well as the electric energy production and consumption rates are investigated and compared. They used regression analysis for prediction of consumption rates for the years of 2010 and 2020 of Turkey's electric energy.Theyalso predicted the distribution of future electrical power supply developed and investments by using linear mathematical optimization model of mainlandTurkey.

A.Ünler had improved energy demand forecasting using swarm intelligence. In his study he proposed a model based energy demand forecasting (PSOEDF) by using particle swarm optimization (PSO), to forecast the energy demand of Turkey.Despite ofother indicators like gross domestic product (GDP) and population were exist; he used import and export as basic energy indicators of energy demand.

S.Kucukali, K.Baris(July2009)had developed fuzzy logic approach for forecasting short-run gross annual electricity demand. Contrary all the other forecast workson Turkey's electricity demand, they used only one parameter for forecastingthe gross domestic product (GDP) which is based on purchasing power parity.They have used historical data from year1970 and they forecast till year 2014. Their model average absolute relative error was 3.9 percent.

M. Kurban. And U. BasaranFilik used Autoregressive and Artificial Neural Network Models Based Short-Term Load Forecasting for Unit Commitment Scheduling. In their study, unit commitment (UC) problem was solved for an optimum schedule of generating units based on the load data had forecasted by using Artificial Neural Network (ANN) model and ANN model with Autoregressive (AR). Total costs calculated for the actual load and two different forecasting load data are compared. They used MATLAB to implement all analysis; they used four units fromTuncbilek thermal plant which located in Kutahya region. The data used in this analysis is taken from TEAŞ and EUAŞ.

İ. I.Esener, T.Yüksel and M.Kurban had used hybrid structure for short-run load forecasting without temperature data. In their study, they had developed ANN, Wavelet Transform & ANN, Wavelet Transform & RBF Neural Network, and EMD & RBF Neural Network for 24-hour-ahead load forecasting without temperature data for Turkey. The average MAPE value was about 3 percent.

# 3. SCOPE OF STUDY

The need of new legislation in electric market has turned electricity into a traded commodity in nowadays; it is sold and bought at market prices. This brought liberalization in pricing mechanism, and forced electric companies and new investors to analyze and predict the market's future in the long run and short term prices. In addition, the electricity is of distinct characteristics, except that of pumped-storage hydro plants, which cannot be queued and stored economically.

As we mentioned in previous sections, like any other liberal market the marginal long run price always depends on long term demand. This knowledge led us to focus on demand forecasting since pricing might not be matched directlyto a specific function or a model, because the fuel resource in power plants is not constant and the pricing is not always related to the cost of generation.

## 3.1 DIFFERENT APPROACHES IN PREDICTION

Two methods can be employed for forecasting hourly load and market prices. The production of cost simulation is considered as a first method which stands the countries' criteria for electricity usage. The second involves application of statistical methods or mathematical approach to forecast price directly or indirectly using historical market data.

Simulation models simulate supplier dispatch though a specific period of time. These models use statistical methods to identify the parameters to match predefined rules based on the historical data and use the models to forecast the future electricity prices, based on the parameters and rules learned from the existing data.

The soft computing techniques, or in other words artificial intelligence techniques, do not model the system; instead, they find an appropriate mapping between the time series, temperature and the electricity price, which is learned from historical examples, thus theyare computed more efficiently. The most popular artificial intelligence techniques are Autoregressive Integrated Moving Average (ARIMA), Fuzzy Logic, Support Vector Machine, Genetic Algorithm, Linear Regression and Artificial Neural Network.

Despite the electricity market, at this point the prices still reflect dispatch costs more than competitor bidding. This means that there is still lack of investment which leads to a lack of competition in the electric market.

## 3.2 ARTIFICIAL NEURAL NETWORK

Despite the fact that neural networks are simple, they are powerful and flexible tools for software forecasting. If the data provided is enough for training. These neurons first were invented in 1943 by Warren McCulloch, a neurophysiologist, and Walter Pitts, a logician, who first worked together at the University of Chicago. Alan Turing proposed the first concept of a neural network in 1948 through his paper “Intelligent Machinery” in which he called them "B-type unorganized machines".

The most attractive side of a neural network isits ability to estimate any nonlinear function and solve problems in which the relation between inputs and outputsis not well defined or easily computable, because neural networks are data-driven.Compared to other machine learning solutions, neural networks are easy to implement and have good performance with less computation time. A neural network functions similarly to the human brain in certain ways. Since they have the ability to fit on non-linear statistical data, they can be used to model complex problems, and may learn the relation between input and output or finding the patterns in data.

An artificial neuron is the simplest unit of a neural network that can manage complex behaviors by the connections between the processing neurons and weight parameters of those connections. Here the ‘network’ in the field of machine learning software refers to the connections between the neurons in different layers of the system. The feed-forward networks are those interconnections that do not form any loop. If loops are used as interconnection between layers, they becomerecurrent or non-feed-forward networks.

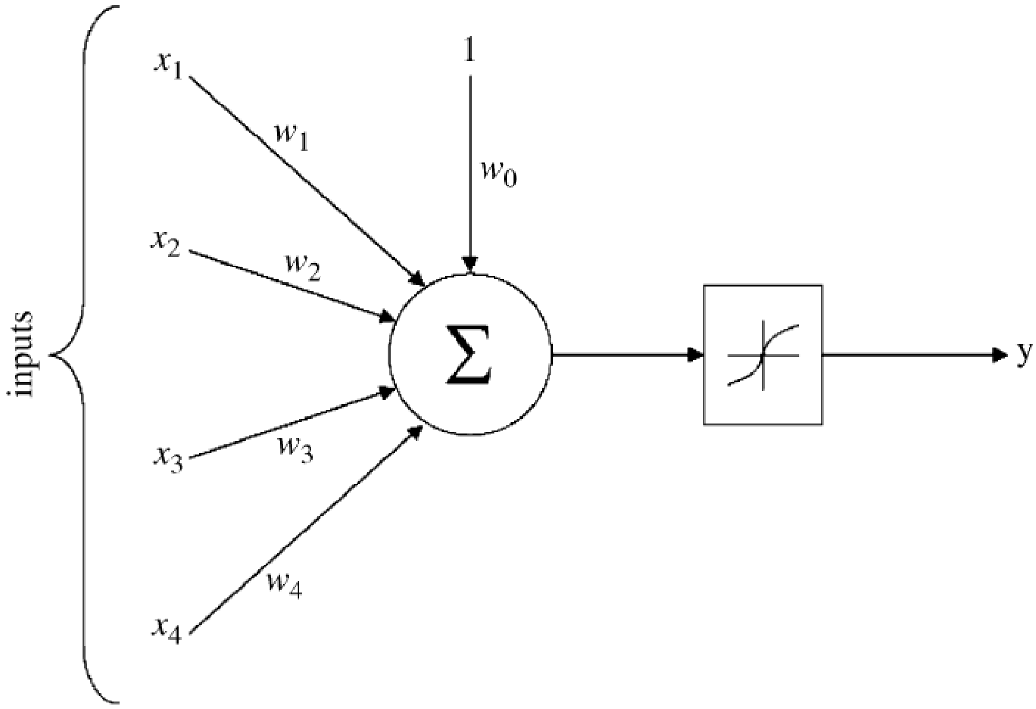


**Figure 3.1: Internal structure of a neuron**

The arrangement of units defines the network architecture. In feed-forward networks, there is an input layer, one or more hidden layers and an output layerwith units arranged in layers. In an input layer, the same input could be shared with all neuron units. The input layer units, without any processing, serve only for transferring the input data to rest of the network. It could consider that all learning processes done on hidden and output layer. Ina fully connected neural network, every neuron in an input or hidden layer is connected to all of the neurons in the following layer.

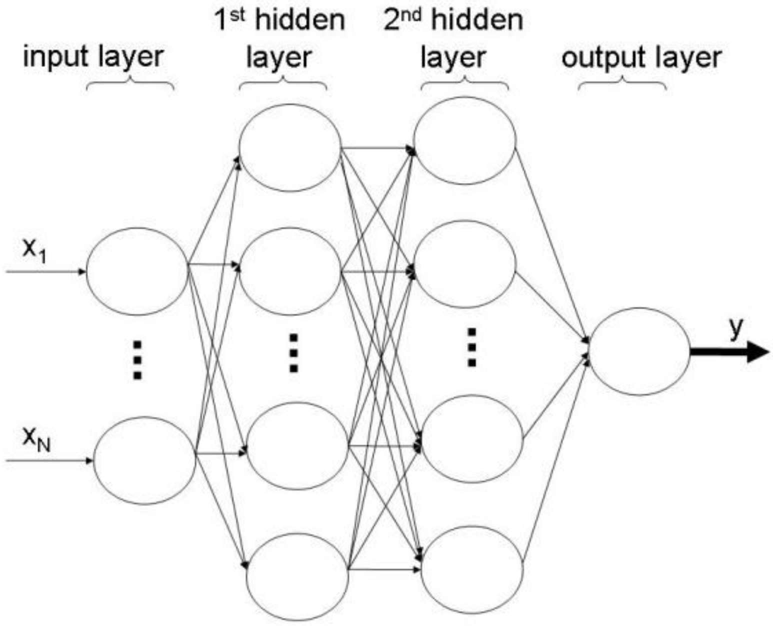


**Figure 3.2:Feed-forward ANN architecture**

The network in Figure 3.2 consists of four layers with two hidden layers. In a four layer network the first layer is considered as the input layer which feeds the network through the connections between the first and the second layer, and then to the third and the fourth layers, the latter being the output layer. In a typical architecture there is ONE input layer (which can have many neurons), ONE output layer (which can also have many neurons). The number of hidden layers can be zero, one or higher in some of the complex systems. Weights between each connection are the coefficients that manipulate the output data in the calculations.

There are three critical parameters in an artificial network:

a. The connections between neurons in layer
b. Learning process to update the weights of the connections
c. The activation function in each neuron

Mathematically, the structure of neural network function$f(x)$ could be expressed as a compound wherein the other functions$g_i(x)$, in which it's very convenient with the network's arrows which show the dependencies between variables, The most used composition function in this scope is*nonlinear weighted sum*, which $f(x) = K(\sum_i w_i g_i(x))$, here $K$ is the activation function which is predefined and in most case it'shyperbolic tangent. It is suitable for the following to express to a collection of functions $g_i$ as simply a vector$g = (g_1, g_2, \ldots, g_n)$.

Once the network has ability to learn, it attracts the most interest. Given a number of inputs and a *class* of functions to predict.learning means using a set of pattern relations and observations between inputs and output to forecast$f \in F$which solves a specific task in some problems.The learning machine learning could be dividing into three major parts, supervised learning, unsupervised learning and reinforcement learning. Supervised learning is used in our solution.

The supervised learning is learning via the history of dataset, a set of example pairs $(x, y)$ , $x \in X, y \in Y$would be given and the aim will be finding function $f: x \rightarrow y$ that fits on the dataset. Also it could say that, learning is a wish to express the mapping implied by the data; the error rate is defined by the cost function which it is the mismatch between outputs of function and real output of domain data.

The cost function is chosen to minimize the mean squared error between the network's output$f(x)$, and the target value $y$ over the entirehistoric data. In most cases, the mean-square error is acceptable as a cost function. Some learning algorithms minimize this cost by gradient descent by implementing back propagation algorithm to converge the cost function.Various forms of gradient descent have been used to train artificial neural networks. In gradient descent the minimization is done by taking the derivative of the cost functionwith respect to the network parameters and then changing those parametersuntil convergence.

For training neural network with gradient descent, each loss function with respect to each weight$w_{ij}$should be computed the gradient G of the network. Adding and subtracting values from each weight affects the overall error E of network. The splitting of loss function into separate terms for each point p in the whole datagains us:

$$E = \ _p E^p \quad , \quad E^p = \frac{1}{2} \ _o f(x)_o^p - y_o^p \ ^2 \qquad (1)$$

Here the ‘p’ is the denotation for the training point and ‘o’ ranges over the output units. As it known that the differentiation and summation are exchangeable, as well the gradient could split into separate constitutions for each iteration point:

$$G = \frac{\partial E}{\partial w_{ij}} = \frac{\partial}{\partial w_{ij}} = \quad _p E^p = \quad _p \frac{\partial E^p}{\partial w_{ij}} (2)$$

After, the computation of the gradient for a single data point would be handling.In order to make the notation much easier and readable, we delete the superscript ‘p’.
Here the chain rule has been used to decompose the gradient into two factors:

$$\frac{\partial E}{\partial w_{oi}} = \frac{\partial E}{\partial f(x)_o} \frac{\partial f(x)_o}{\partial w_{oi}} \qquad (3)$$

By differentiating the Eqn. 1, first factor can be attained:

$$\frac{\partial E}{\partial f(x)_o} = \ f(x)_o - y_o \qquad (4)$$

Where our hypothesis for each node is:

$$f(x)_o = \quad _j w_{oj} x_j \qquad (5)$$

The second factor becomes like below be using Eqn. 5:

$$\frac{\partial f(x)_o}{\partial w_{oi}} = \frac{\partial}{\partial w_{oi}} \quad _j w_{oj} x_j = x_i \qquad (6)$$

By replacing equations 3 and 6 together, we get

$$\frac{\partial E}{\partial w_{oi}} = \ f(x)_o - y_o \ x_i \qquad (7)$$

By summation each of the weights with the contribution given by the equation 6, the gradient G could be found for the entire data set. After, it could subtract the learning rate μ of G from the weights to perform gradient descent. For a simple training node the update rule for weight w will like:

$$w_j = w_j - \mu \; f(x) - y \; x_i$$

Simple nonlinear function such as sigmoid function could be seen in most cases in neuron of network as an activation function:

$$f \; x \; = \frac{1}{1 + e^{-x}}$$

Since the ANN has theability to fit on functions, it has many application areas. Within system identification and controls, there are many important applications such as control mechanisms (vehicle control, process control) and some intelligent applications such as game-playing and decision making (chess, backgammon, racing), sequence recognition (gesture, speech, handwritten text recognition), pattern recognition (face identification, object recognition, radar systems), and also it influenced human lives directly in medical field, such as medical sciences (diagnosing tumor cells), e-mail spam filtering and visualization, and also it plays an important role on market and countries' spot markets as a financial data mining tool (knowledge discovery in databases, "KDD").

In this work, a neural network approach is used to predict the next-day load in the electricity market of Turkey. Three-layered feed forward neural networks are generated with nonlinear transfer functions are trained for forecasting. Hyperbolic tangent sigmoid functions are used for the hidden layer and linear functions for the output layer. The Levenberg-Marquardt algorithm is used to train a three-layer feed-forward neural network. To find the optimum network architecture, it's recommended to test several combinations in forecastingwhich includes testing different types of transfer functions, different number of units in each layer and different number of layers in network.

### 3.3 THE MASSIVE NEED FOR SHORT RUN DEMAND FORECASTING

The value of price forecasting has become very high in the electric market afterthe market development regulation was published in 2001.

In a deregulation market there are two different trading strategies; the pool and bilateral contracts trading. In pool trading, the producers and consumers submit their bids and offers on a digital environment respectively for selling and buying country's electricity on an hourly basis. Finally, a market operator EMRA (Energy Market Regulatory Authority) clears the market by approving the fit offer and demand in which the selling and buying are performed.

Companies that trade on pool in electricity market or power generator companies, who offer bids in the market, need hourly market demand to decide whether to bid their generation capacity on a day ahead spot market or power market. In case the prediction of National Load Dispatch Center stays below the total generation plan of power plants, bid in the power market will be more efficient since the price will be higher.

The same case is valid for trade companies; they can use the advantage of the two markets, just buy and sell to the market without any deal with end users.

Simple regression techniques have been implemented by The State Planning Organization (SPO) which beheld the first applications on energy demand forecasting. The first Modern econometric techniques for energy planning in Turkey were applied in 1984.

The International Atomic Energy Agency (IAEA) has developed a model for analysis of energy demand (MAED) which is one of these modern econometric techniques for simulation model. The Ministry of Energy and Natural Resources of Turkey (MENR) has started using MAED for predicting the medium and long run energy demand which is mostly related to investors for calculating their return time and guarantee the return of investment.

These study focuses on short term demand forecasting depart from long run; is useful in operational scope of energy market.

Energy estimating modeling has always been the most attractive issue in turkey and worldwide, it has been subject to most academic and research dissertations under different technique and analyzes. Within the new regulation of energy market, one new subject is added which is price forecasting due to dynamic pricing technique. Statistical models are also considered by Ediger and Tatlıdil for energy forecasting, they used winters' Exponential Smoothing Method and Cycle Analysis for Primary energy demand. Linear Regression for electricity demands forecasting used by Yumurtacı and Asmaz. Akay and Atak used Grey Prediction with Rolling Mechanism (GPRM) for Electricity demand forecasting. Autoregressive Integrated Moving Average (ARIMA) used by Ediger and Akar for Primary energy demand forecasting. Erdoğdu used Seasonal Autoregressive Integrated Moving Average (SARIMA) for Electricity demand. Toksarı used Ant Colony Optimization (ACO) for Electricity demand. Hamzaçebi used Artificial Neural Network (ANN) for Electricity consumption. Sözen and Arcaklıoğlu used (ANN) for Energy consumption. Ceylan and Öztürk used Genetic Algorithm (GA) for Energy demands forecasting.

## 3.4 OVERVIEW OF DATA

The real electric data used in the estimating the process which taken from Market Financial Settlement Center EMRA (Energy Market Regulatory Authority) daily report window. We used electric hourly price and load from December 2011 till April 2013, 12168 instances of time series data. Each instance has a load, power market price and a day ahead price. However, we added temperature information taken from 3 big cities airport to each instance. Beside that after lots of trial and error on how to filter data we decide to omit weekend and holiday instances from whole series before applying any algorithm for forecasting.

The data divided to three partitions, 70 percent of data used for training artificial neural network, 15 percent used for validation network and 15 percent for test set. The

performance and accuracy of algorithm has been estimated on test set, whereas the algorithm's parameter updates according the validation set.
The back propagation algorithm was done on training set while simultaneously validation was done on the same set.

It's necessary to apply a discrete operation on all data before applying any model, we converted date from calendar to week days and year months by assigning discrete number to each of them.

## 3.5 MODEL IDENTIFICATION

In all forecasting models, model identification is used as a common way. In model identification stage, aim is to analyze which polynomial function and parameters should be guessed or found, since forecasting is fitting points from n dimensions on a specific polynomial function.

Generally, for forecasting purpose, hardware solution or software programming could be used to estimate the demand. Time series analysis and simulation approaches could be categorized within hardware solution. An existing system model is created and all processes will go on that model in this case. The accuracy of this approach is quite high but it needs much more information, and the computational cost is very high.

The other solution technique is modeling the system by using artificial intelligence method. In this solution we focus and aim on finding a mapping between the several inputs and demand. The mapping is done by training the algorithm on historical data. The computational cost of soft solution is less than once in hardware simulation, the model is very simple, which its accuracy depends on the correctness of inputs which are considered. Within forecasting models there are several mathematical and statistical techniques and some technique uses multiple approaches in parallel. Lots of simulations were performed to forecast the Turkey's hourly demand using MATLAB neural network and WEKA classifiers functions Multilayer-Perceptron approach as well as WEKA Support Vector Machines for considering demand.

For Short-Term Load Forecasting (STLF), Artificial Neural Networks (ANN)have been successfully used in lots of electric utilities.

The test is done on hourly indices which they are sets ofone hours data, this means that our test data consist of sets of different days of hourly load and temperatures.In this study, we considered two accuracy measures, mainly, the mean absolute percentage error (MAPE), and the mean absolute error (MAE), the formula below expresses the definition of the MAPE:

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{f(x)_i - y_i}{f(x)_i} \right|$$

and the mean absolute error (MAE) is defined as:

$$MAE = \frac{1}{n} \sum_{i=1}^{n} \left| f(x)_i - y_i \right|$$

where$f(x)_i$ and $y_i$ are the $i$th actual and predicted hour values respectively, and $n$ is the total number of predictions.

For the best forecasting performance, it is recommended to test several configurations to find the best network architecture. The testing combination should include types of transfer functions and different unit in each layer and different layer size in network and also different types of training algorithms. A specific network configuration is selected after the analysis which consists of anMLP network with two hidden layers, the tangent sigmoid transfer function is used in hidden layers as a transfer function and linear transfer function in in the output layer. After trying different number of neurons in hidden layers we used 50 neurons in each layer. Adding more layer or more neurons to the model might cause over fitting which leads the model to memorize the training set and increase the generalization error.To avoid this we increased the number of neurons and layers gradually.

This network was trained with Levenberg–Marquardt (LM) algorithms.

Couples ofdifferent network and data arrangements were considered as described below.

I. The training set is selected to contain data having a duration of one month and the test set is defined as the day that comes after this period.
II. The test set is selected randomly from the whole dataset with the remaining data constituted the training set.
III. Seasonal data is used separately where for each season, randomly selected hourly data is used as the test set.
IV. Using different input features for trainingthe network.

# 4. CASE STUDIES

A customized neural network approach is applied to forecast the next-day electricity load in the electricity market of mainland Turkey. Load forecasting is computed using historical data of the year 2012. This figure shows the electricity load within one week of the year:

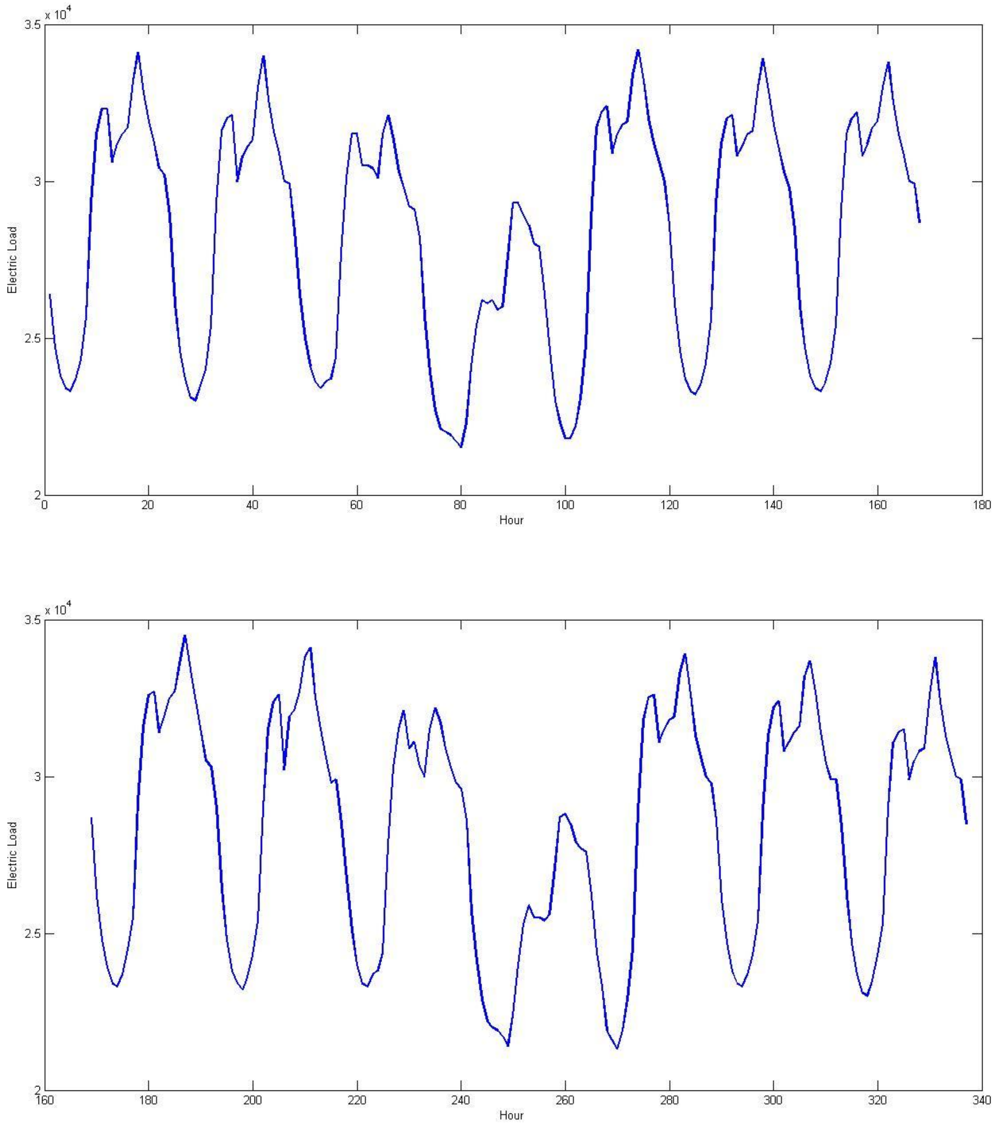


**Figure 4.1: Weekly electricity load of Turkey**

The figures above illustrate that the Turkey electricity load during one week pursue to a specific shape. The oscillation in graphs shows the repeated characteristic similarity within one week (168 hour).

## 4.1 FORECASTING

In a competitive market, the future load and price information is important for risk management and scheduling for companies facing with competitive price in electric spot market. Load knowledge may represent an advantage for market players in trade scope, and price forecasting gives the ability of the company to bid for a strategic spot market in the short term. Since the electricity price is influenced by demand, the load forecasting has an important role in price forecasting. An extreme out boundary data with no assessable reason are the consequence of bidding strategy.

Some factors are more important than others, temperature as well as other weather values effects in the demand, and also the historical demand significantly improves predictions.

Since the consumption in cities changes depending on day profile, the load profile changes from day to day and week to week, which this makes the changes in the behavior of electricity market. Like the load daily price, profiles are also classified as weekdays, weekends and private days, holidays or in another word, Calendar Days.

For the sake of fair comparison, we have used the basic forms of Support Vector Machine and Artificial Natural Networks, which are implemented in WEKA. Here are the accuracy results of both:

**Table 4.1: Comparison between different forecasting techniques**

| Model | Mean absolute error | Relative absolute error |
|---|---|---|
| ANN | 2191.8399 | 62.797 % |
| Support Vector Machine | 2494.782 | 71.4764 % |
| SVM with Normalized Poly Kernel | 2297.4627 | 65.8231 % |
| SVM with RBF kernel | 2384.9765 | 68.3304 % |

The mean value of the load is 27604.29 which mean that the MAPE of basic form of Artificial Neural Network is approximately 12.5 percent, since without any optimizations on WEKA; it uses the simplest form of models. One hidden layer with five neurons, where each of them passed through a sigmoid transfer function was used in the network. Comparing with Support Vector Machine we see that better accuracy is obtained from neural network.

By selecting the kernel function of SVM as thePuk kernel and normalizing thefilter on input data, the accuracy of forecasting has increased, as well as the time to build the model has increased direct proportionally, the mean absolute error has decreased to 750.9042 which is equal to 2.7 percent of MAPE. The total time to build the model was approximately 40 minutes.

The result above led us to focus on developing an Artificial Neural Network. We used MATLAB toolbox for this purpose, since we deal with matrix operations which are easy to handle in MATLAB code.

Problem solving with Neural Network Design tool in MATLAB follows seven steps;

1. Gathering and collecting thedata.
2. Design and building the network
3. Adjustments and Configuring the network
4. Assigning an initiating values to the weights and biases
5. Training and iterating the created network
6. Testing and validate the accuracy of the network

7. Using the networkfor forecasting new instances

We have followed all six steps starting from second one since the first step generally occurs outside the MATLAB environment.

After collecting data and arranging it we used load( ) function to import all data into MATLAB environment. The imported data divided into three parts, 70 percent for training and 15 percent for validation, the remain 15 percent for testing, this done by using dividerand() function in MATLAB.

Like the biological nervous system, a neural network should be trained, then can learn and get conditioned to find solutions which are forecast future load. The strength or weights of connections between neurons in a neural network defines its behavior. This is automatically done by training the network towards a particular desired task according to the rule set by the network cost function. The training continues until the validation error fails to decrease.

We take the advantage of command line functionality of MATLAB Neural Network Toolbox, and generate an instance of network which allows the customization of the network, connection, layer size and also neurons transform function. We also set the bias values of each network as well as the performance and post and preprocessing functions.

We initialize and run the network for training by passing it though init() function " net = init(net) ", this function returns a network ‘net’ with configured weight and bias values which matches with the network initialization function and the parameter values, indicated by net.initParam.

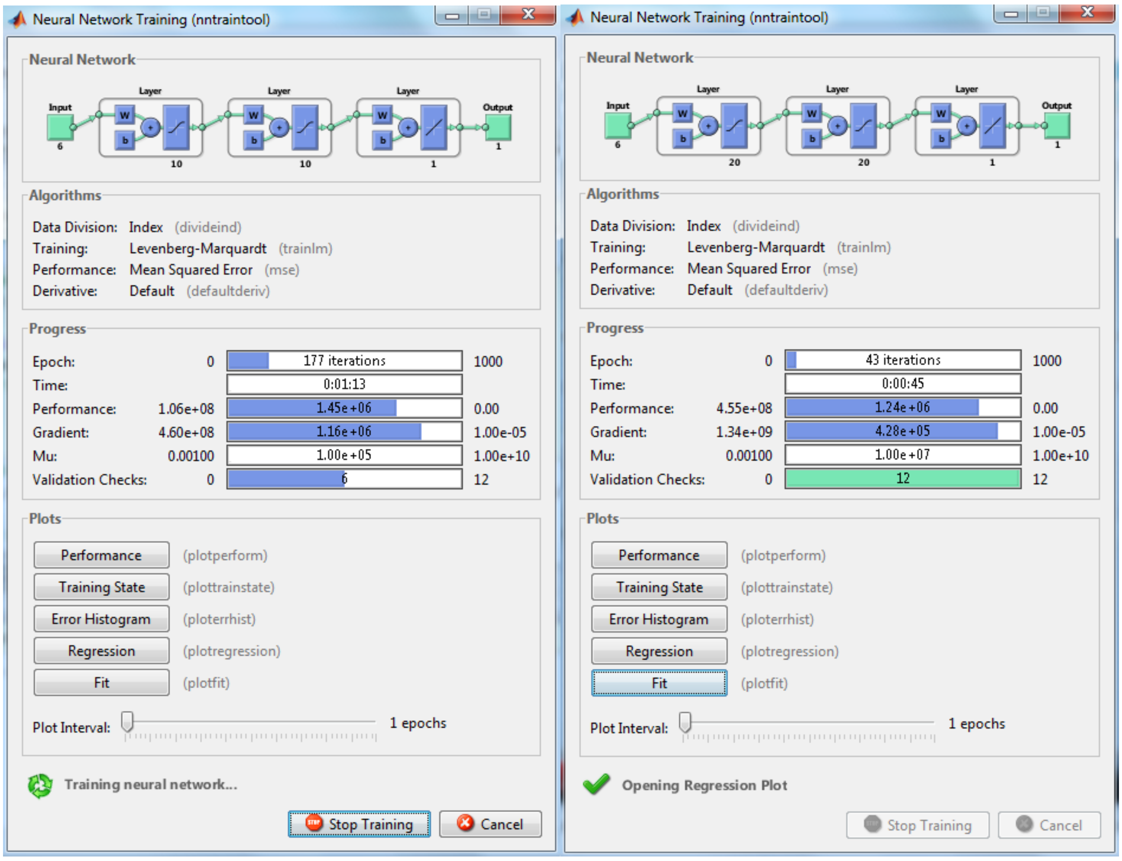


**Figure 4.2:Thetraining interface of MATLAP neural network toolbox**

**Table 4.2: Using different combination for training set**

| Neural Network Model | MAE (MWh) | MAPE |
|---|---|---|
| One hidden layer, 33 neuron | 882 | 3.4 % |
| Two hidden layer, 10 neuron | 848 | 3.2 % |
| Two hidden layer, 20 neuron | 730 | 2.7 % |
| Two hidden layer, 50 neuron | 600 | 2.3 % |

Increasing the network layer and neurons in each layer makes the network more flexible and adjustable for more complex graphs, the more oscillation in load needs more flexible network to forecast.

After twelve iterations and when the validation error increases, the training stops. The results will be acceptable if the following conditions are satisfied:-

a. The final MSE is small
b. The error characteristic of the test set and the validation set are similar
c. There is no any over-fitting signals by performing too many iterations

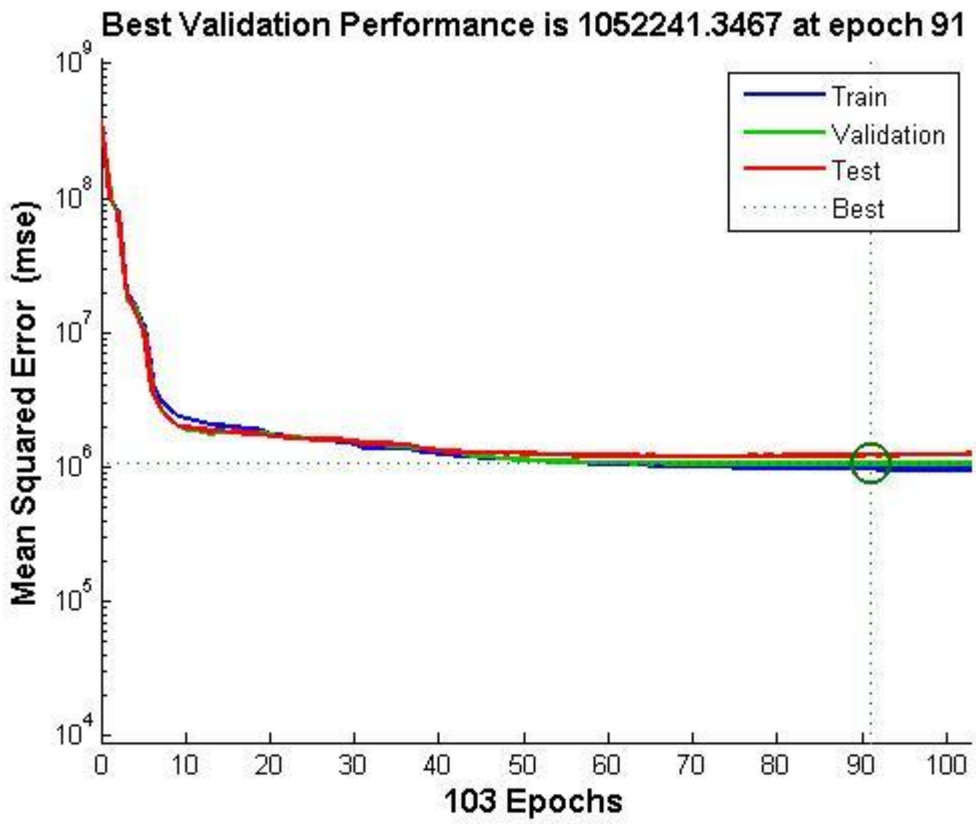


**Figure 4.3: The training process of 20 neurons**

The results above comes from network with two hidden layers and 50 neurons in each layer, it’s acceptable since the decrease in MSE of training graph is very close to validation and test, and also the training set error is below the validation and test set errors with a small gap in between.

For accuracy of our network training we have another criteria such as checking the regression panel

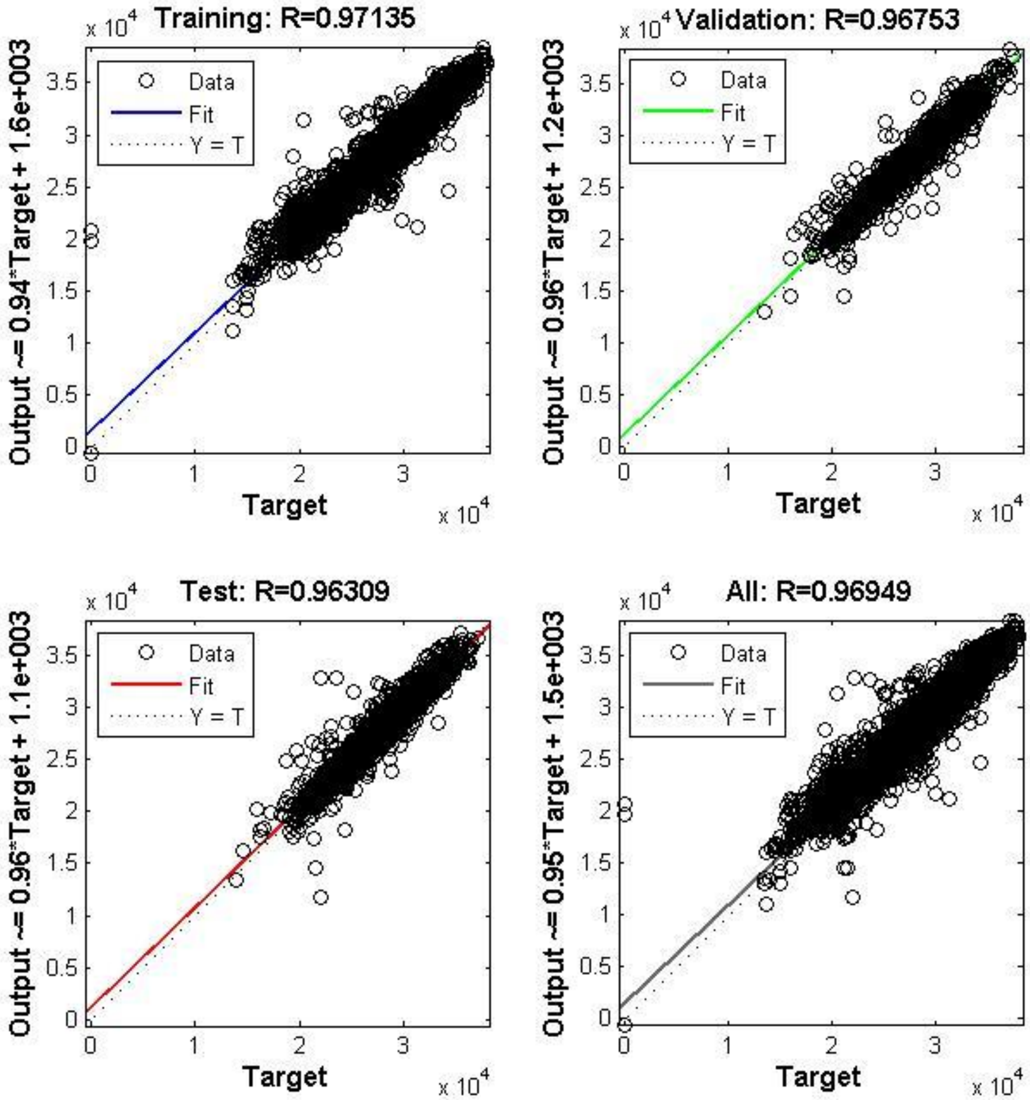


**Figure 4.4: The regression panel of neural network toolbox**

Over-fitting occurs when an artificial neural network memorizes the historic training set without learning to generalize to new test data.This happens when the training R-value is much closer to one instead of the validation and test R-value. Over-fitting generates relatively small error on the training set but not on test and validation i.e., when new data is presented to the network.

The result of regression is comparably good, since all the training, the testing as well as validation R- value is near to 1, they are over 0.95.

The error histogram of network shown in figure below illustrate that the maximum error is about 2944MWh. The network also predicted higher error but we assume them noisy data or out layer, so the average of whole prediction is acceptable.

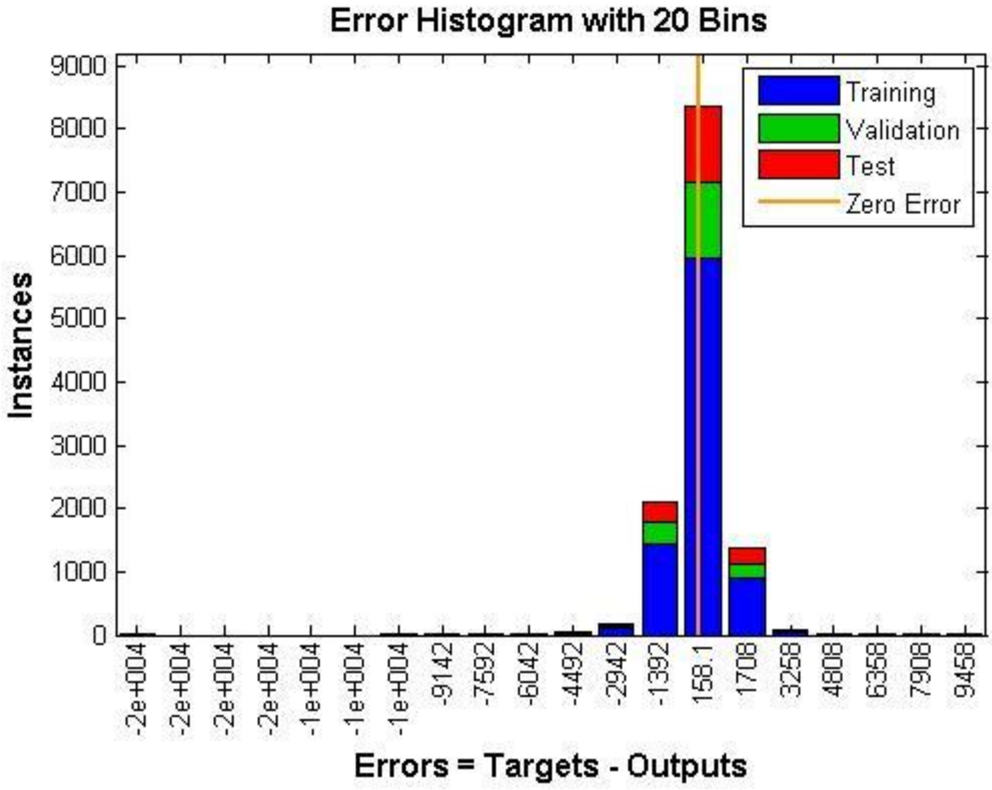


**Figure 4.5: The error histogram of forecasting data of neural network**

The most productive method in solving complicate problems is following the lemma "divides and conquers" in order to be able to solve the complex systems separated into simpler elements and branches, also simple elements may be gathered to produce a complex system (Bar Yam, 1997). Dividing whole dataset into sub sets according specific characteristic gives us two advantages; first, more accurate results due to more similarity between training set and test set, second, avoid over-fitting since the large training data causes network to memorize the training rather than learn to forecast. Training the network more than needed deteriorates the accuracy of forecasting results.

For the Turkish market the winter weeksis from December to February, the spring from March to May, the summer from June to August and the fall from September to November.

**Table 4.3: The error metrics for each season separately**

| Model | ANN 2 hidden layer 40 neurons | Support Vector Machine with Pukkernel |
|---|---|---|
| winter | (MAE): = 743 (MAPE): = 2.7 | (MAE): = 820 (MAPE): = 3.1 |
| spring | (MAE): = 543 (MAPE): = 2.0 | (MAE): = 687 (MAPE): = 2.5 |
| summer | (MAE): = 1018 (MAPE): = 3.55 | (MAE): = 1015 (MAPE): = 3.48 |
| fall | (MAE): = 983 (MAPE): = 3.7 | (MAE): = 928 (MAPE): = 3.4 |

**Table 4.4: The error metrics for each season data separately without using temperature value**

| Model | ANN 2 hidden layer 40 neurons | Support Vector Machine with Puk kernel |
|---|---|---|
| winter | (MAE): = 1271 (MAPE): = 4.76 | (MAE): = 1011 (MAPE): = 3.5 |
| spring | (MAE): = 673 (MAPE): = 2.48 | (MAE): = 831 (MAPE): = 3.05 |
| summer | (MAE): = 1680 (MAPE): = 6.04 | (MAE): = 1717 (MAPE): = 6.48 |
| fall | (MAE): = 1464 (MAPE): = 6.28 | (MAE): = 1798 (MAPE): = 7.4 |
| Whole data | (MAE): = 1007 (MAPE): = 3.7 | (MAE): = 1374 (MAPE): = 5.6 |

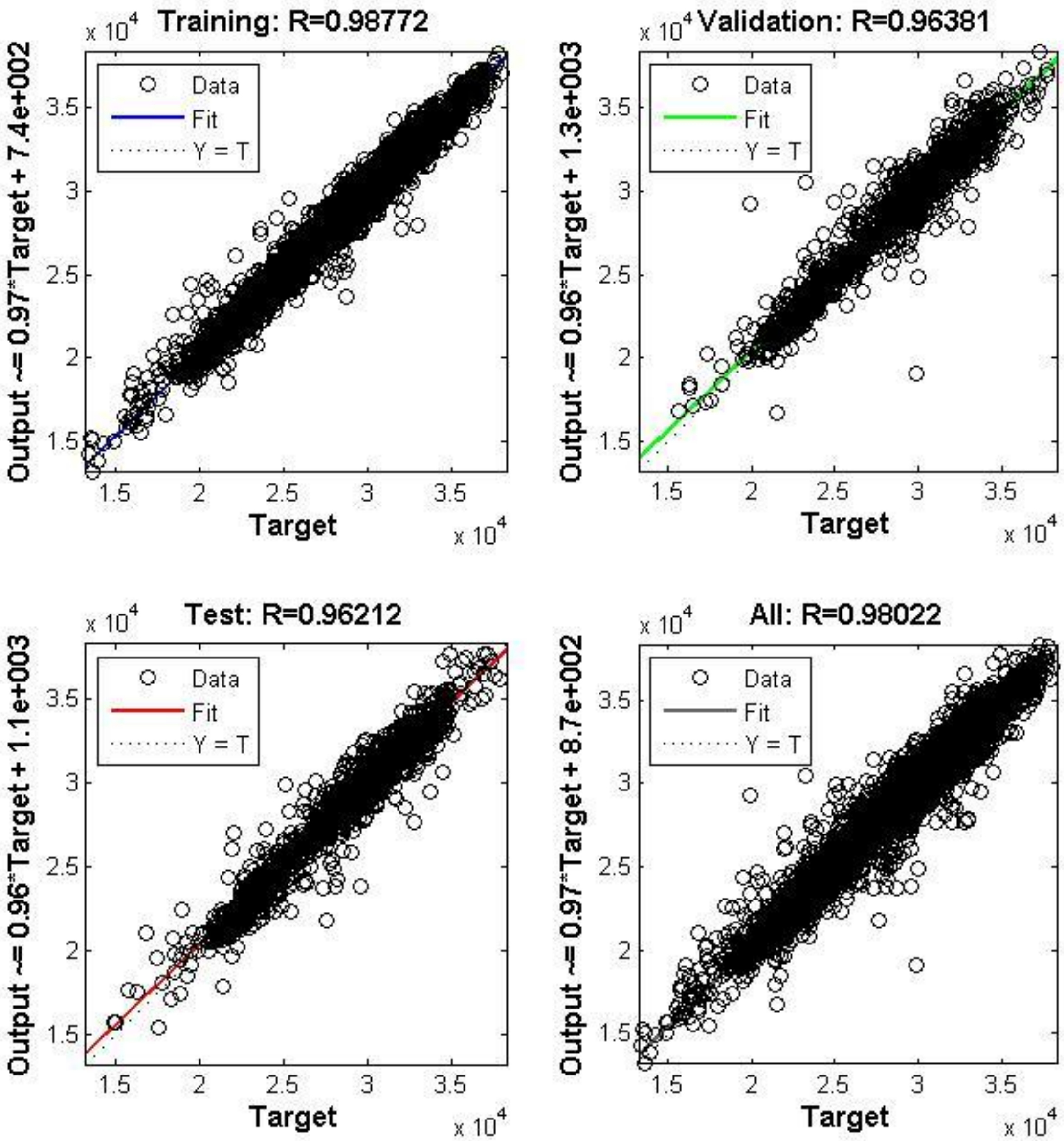


**Figure 4.6: The regression diagram for winter season**

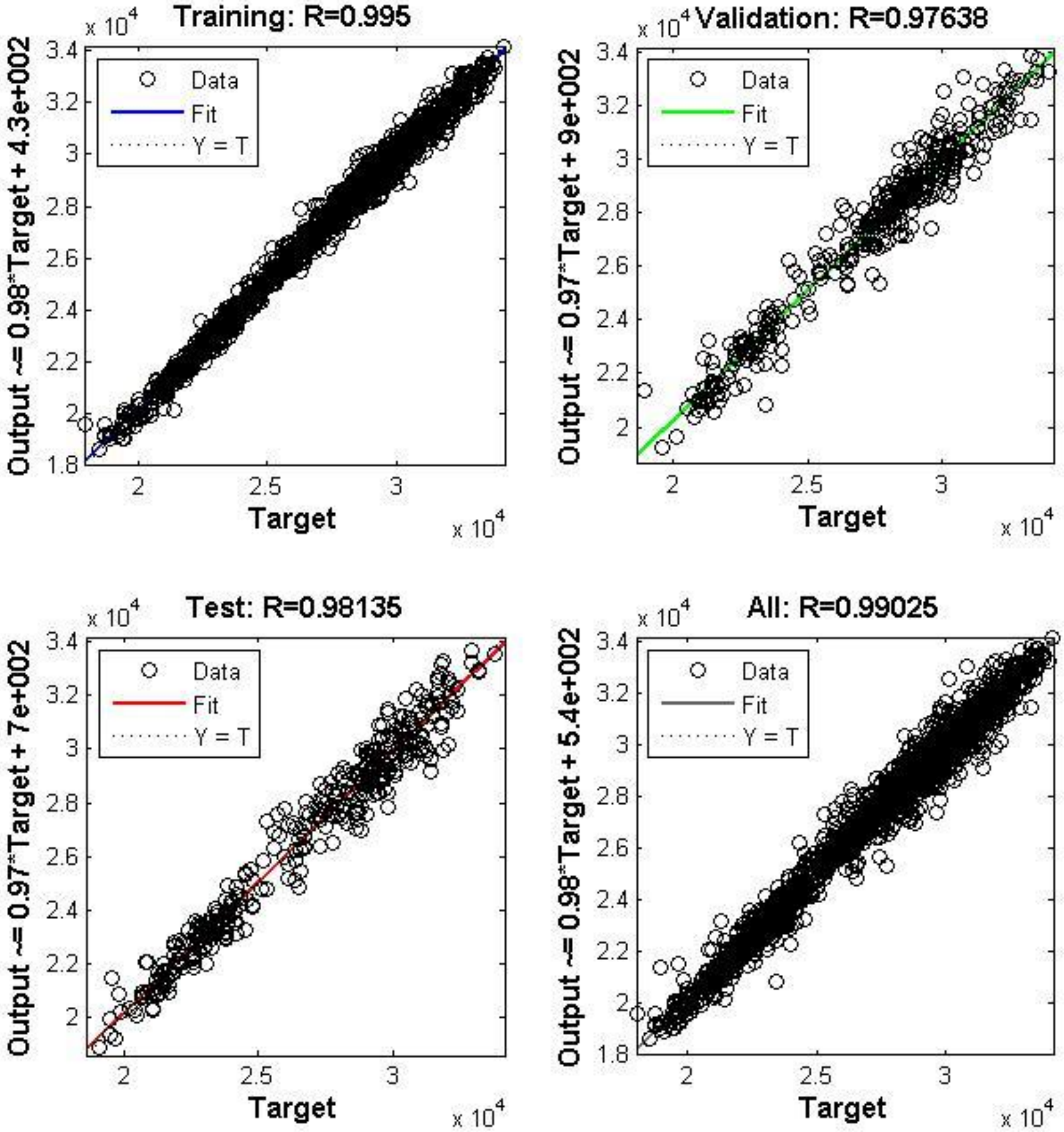


**Figure 4.7: The regression diagram for spring season**

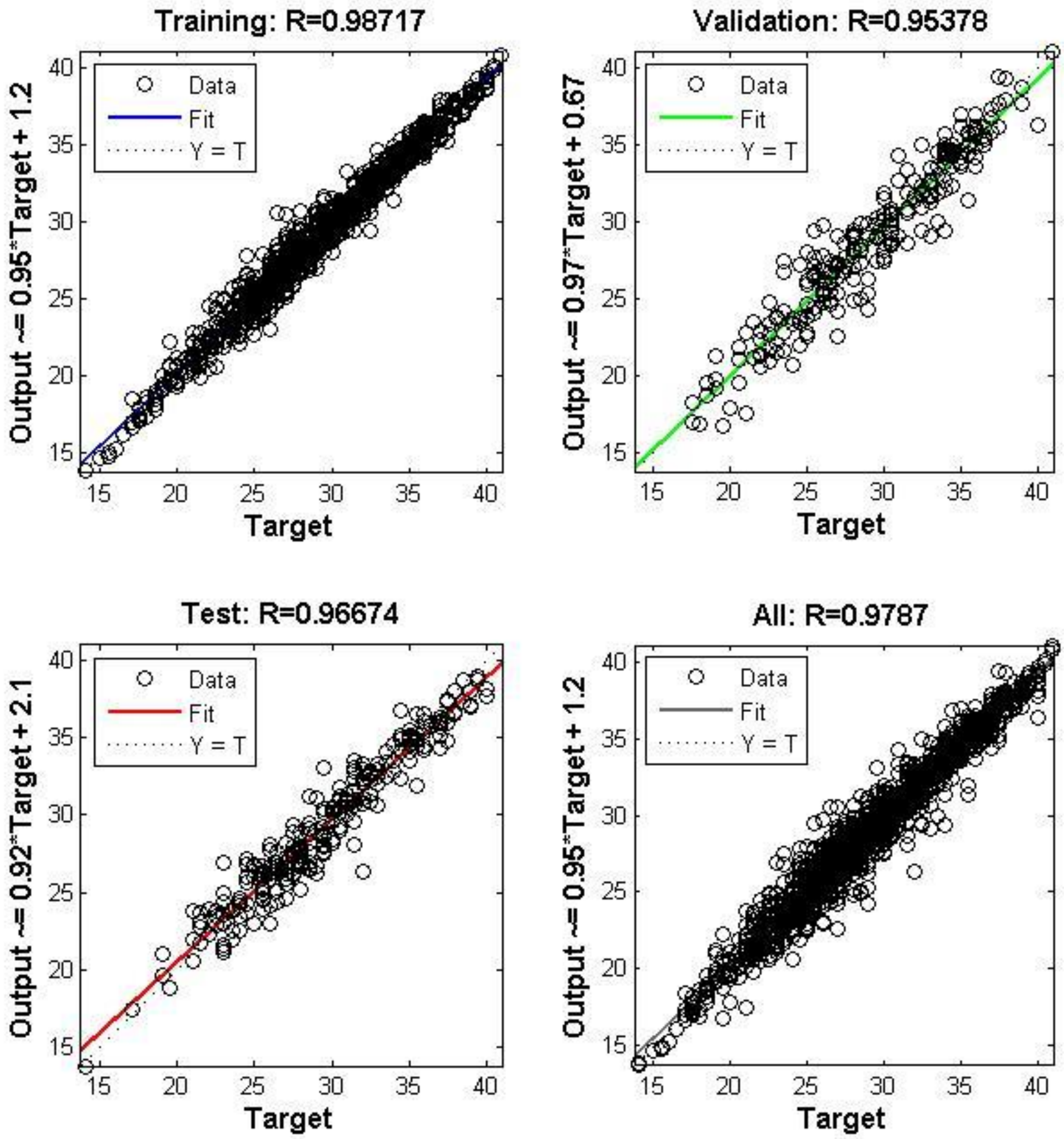


**Figure 4.8: The regression diagram for summer season**

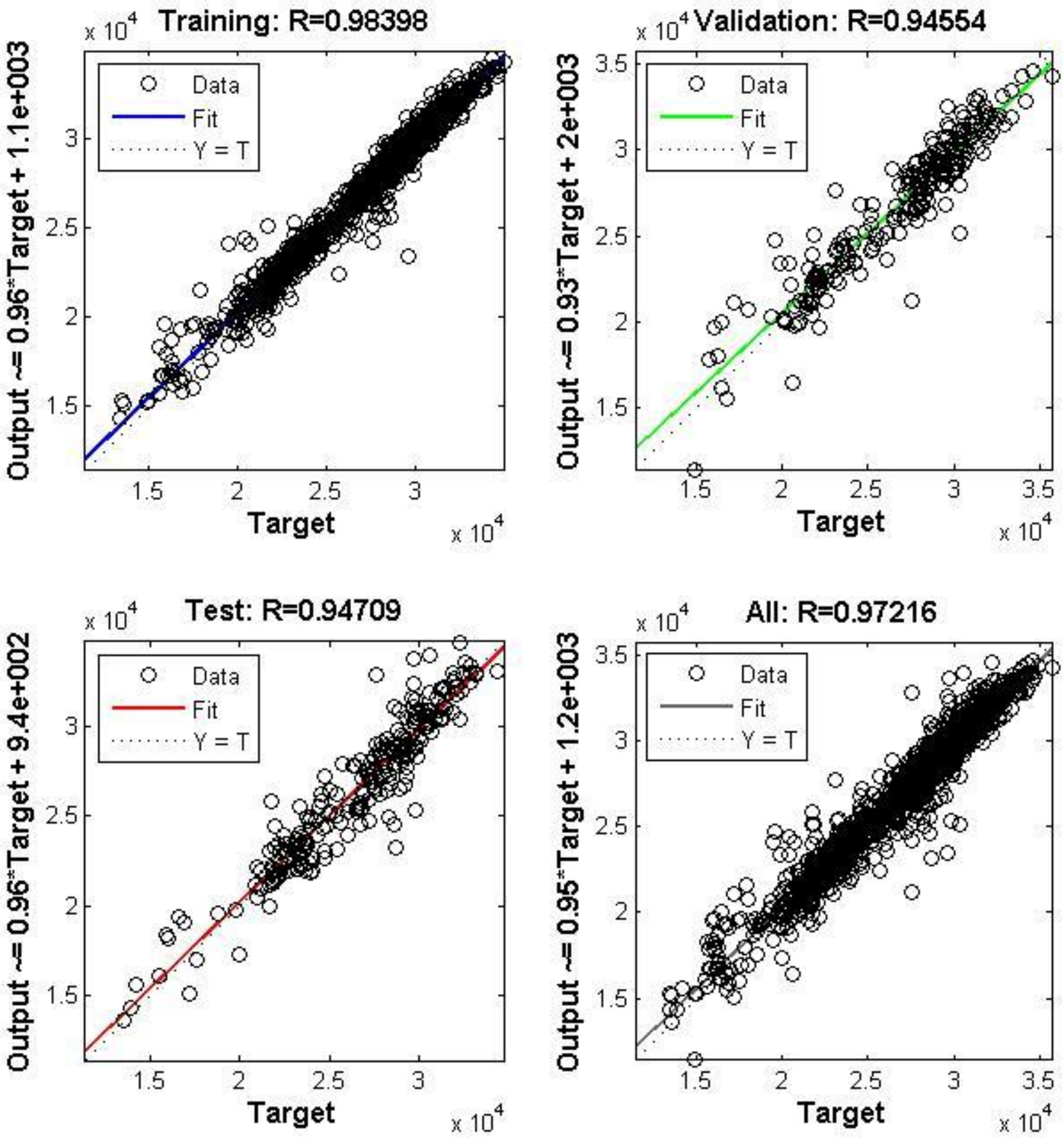


**Figure 4.9: The regression diagram for fall season**

To further investigate the validity of our predictions, the error rate of hourly load forecasting has been compared toeach hour's mean price. The importance of smaller error rate increases at high market spot price. Therefore to obtain more accurate predictions, separate neural networks are trained for each hour of the day that belongs to a given season.Figures below illustrate the four different season's graph mean absolute percentage error and mean prices for 24 hour separately.

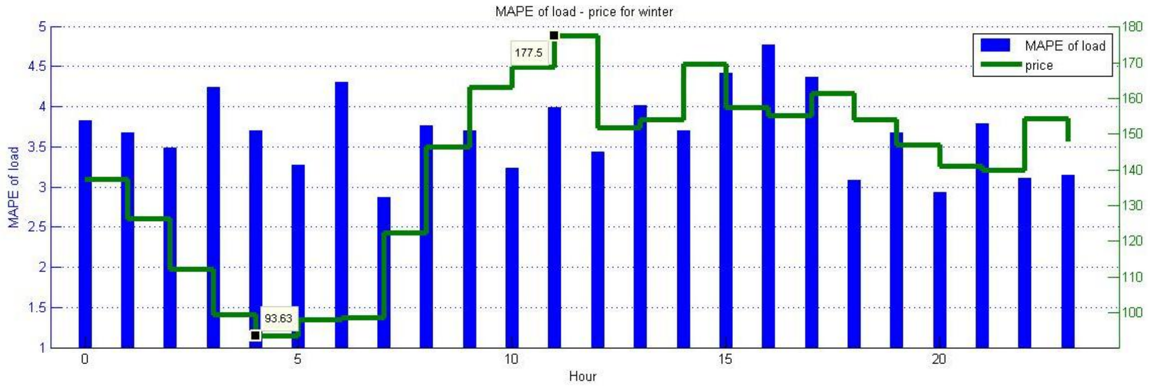


**Figure 4.10: Winter hourly forecast**

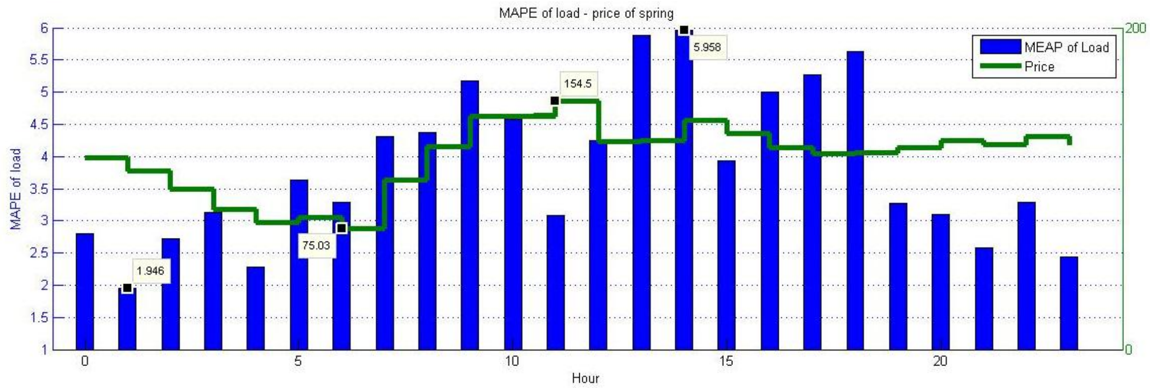


**Figure 4.11: Spring hourly forecast**

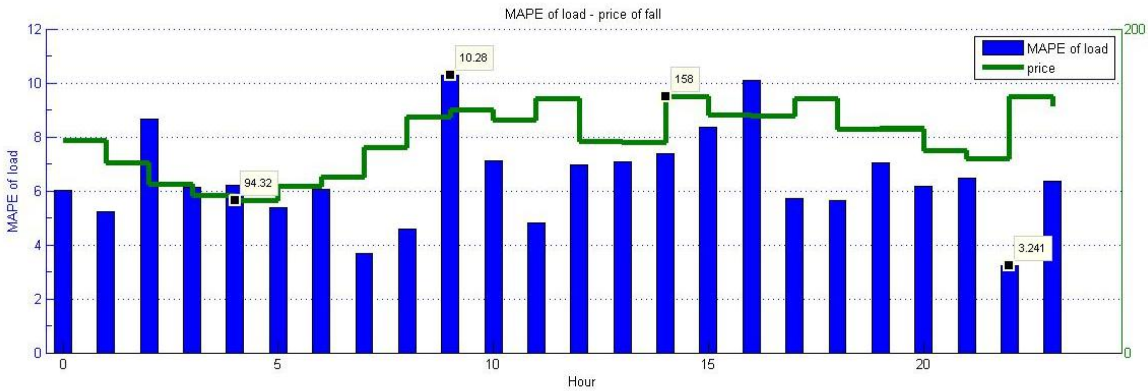


**Figure 4.12: Fall hourly forecast**

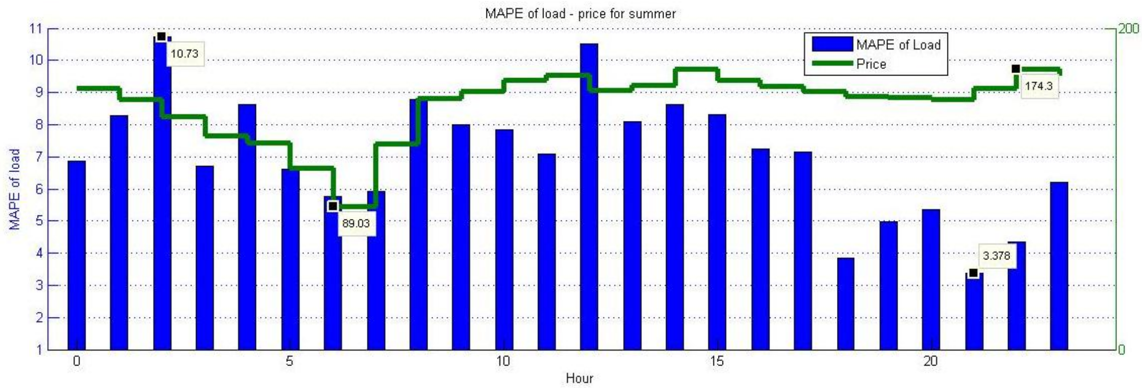


**Figure 4.13: Summer hourly forecast**

For some trade companies the forecasting accuracy computed on different periods of the day is important. We separate the whole dataset into those three period subsets which consist of:

a) daytime starts from 06:00 to 17:00
b) evening starts from 17:00 to 22:00
c) nighttime starts from 22:00 to 06:00

The table below shows the accuracy result of the network with two hidden layers and 40 neurons in each layer, the input parameters are the temperature and time series data:

**Table 4.5: The error metrics based on three periods**

| Time period | MAE (MWh) | MAPE |
|---|---|---|
| Daytime | 958 | 3.5 % |
| Evening | 879 | 3.0 % |
| Nighttime | 768 | 3.2 % |

# 5. CONCLUSION

Since 1994, Turkey's electricity sector has been fundamentally changing. Within this scope, it has been separated into two different state economic enterprises, Turkish Electricity Company (TEAŞ) and Turkish Electricity Distribution Company (TEDAS). This followed in 2001 with the new Electricity Market Law (number 4628) which (TEAŞ) has been restructured as Electricity Generation Company (EUAŞ), Turkish Electricity Transmission Company (TEIAŞ) and Turkish Electricity Trading and Contracting Company (TETAŞ). With this kind of flexible structure, new spot market legislation has been developed.

New investors with new needs have emerged and the country's future demand forecasting importance has gained more importance. Manpower for the operations and financial predictions has replaced the engineers. The short term price and load prediction has become the most important subject for market players who compete in spot market.

In this study,software in MATLAB has been developed for Artificial Neural Network, which aims to forecast Turkey's short term electricity demand. A one year data and hourly temperature has been used as a time series to train the network. Within this frame, several versions of data set have been used. A one year historical data has been separated to four seasonal subsets, in which all of those sets contain three big city's temperature and hourly historical load. Each of the subsets was separately tested and the accuracy measures are compared with different forecasting methods.

Within this scope we obtain some essential results of which are listed below:

a. Hourly electric load graph has high frequency and repeated characteristic within a weekly period. This shows that in a near time period, the characteristic of load is very similar and is predictable excluding some outlier exceptions.

b. The relationship between load and cities' weather cannot be interpreted linearly, there is no single coefficient value for each temperature to match the load in a specific hour.
c. The error histogram of test set generally shows that the mean absolute percentage error (MAPE) value is not valid for all hours in a forecasted day, some errors stay above the mean absolute error (MAE) while some are very small.
d. By using an Artificial Neural Network, we obtain better results than Support Vector Machine, but in some cases Support Vector Machine is better with long training time.
e. The private investment on electric generation has rapidly increased after electric market law 4628 has been passed. This illustrates that the law has insured the supply security.
f. Dividing the whole dataset into subsets with specific characteristics has two advantages; first more accurate results due to a higher degree of similarity between training and test sets, second over-fitting can be avoided since the large training data causes the network large number of iteration and led to memorize the training rather than learn to forecast. Over-training the network deteriorates the accuracy of the results.
g. The electricity load of country is influenced by big city's temperature value, however accurate and detailed weather data has a direct effect on Turkey's electricity consumption. Omitting temperature decreases the forecasting accuracy.

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