Abstract—TENS (Transcutaneous Electrical nerve Stimulation) is explained as stimulating nerves via skin to decrease the pain. The studies about TENS were related to investigate its effects on animals and humans. In this study, the problem is to improve a TENS model by investigating the effective parameters in humans. Skin conductance and skin thickness were chosen as effective parameters. By considering the ailments which cause pain, four implementation zones were studied. For modelling, ANFIS (Adaptive Neuro – Fuzzy Inference System) was employed. Average Training Error changes between 0.149-0.533, while Average Testing Error changes between 0.823-1.0815. This corresponds to maximum 1.0815 mA swing in the electric current that is applied to patient. This swing doesn’t cause a negative effect on patient. By means of this study, time saving and minimizing human originated errors were provided while applying TENS. Besides, TENS can be applied on the patients who have communication difficulties.

Index Terms—TENS, skin impedance, skin thickness, ANFIS

I. INTRODUCTION

Pain is a disturbing case that originates from ruin of texture. Besides, pain is a stimulator and a protection mechanism that causes various somatic, autonomic and sensuous responses to protect the balance of body [1]. Many investigations are performed for finding a treatment method that obviates the pain with fewer side effects, effectively [2]. Nowadays, TENS has become a very effective alternative treatment method since the use of drugs for chronic and perennial pain causes the desolation risk of kidneys and liver. In TENS method, electric current is used to stimulate the nerves with the help of electrodes which are placed on the skin [3].

II. MATERIAL AND METHOD

In this section, the collected data and the improved ANFIS model has been explained, briefly.

A. Data Set

The concerned measurements have been carried out by employing 113 patients. Four implementation zones have been selected by considering the ailments which are met. The exceptional cases (for e.g. sense loss because of having no nerve transmission) have been eliminated. Thus, the number of patients has been reduced to 90. Names of the zones have been formed by considering the contact points of electrodes. The information about the selected zones has been provided in Table I.

In this study, skin conductance and skin thickness have been selected as the effective parameters on TENS. The amount of applied current to the patient has been investigated according to these parameters, so current has

Fig. 1. Block diagram of modelling via ANFIS.

The use of electrical current for pain relief dates as far back as the Egyptian era; however, the concept of electrical stimulation analgesia was not supported by a scientific theory until the publication of the gate control theory in 1965 [4]. Till nowadays, studies about TENS have been related to investigate its effects on animals and humans like mentioned in the studies of Walsh et al.(1995, 1998), Solomon et al. (2003) and Reeves et al. (2004) [5-8]. Differently, in this study, as a new approach, the effects of physiological parameters in humans have been investigated while application of TENS. By basing on the performed investigations, skin conductance and skin thickness have been chosen as the effective parameters. By basing on these parameters, modelling of TENS method via ANFIS has been performed.

Fig. 2. Training and testing errors of Zone 1.
been considered as the output. It has seen that the amount of implemented current on same zone of the same patient could change as implementing TENS. It has detected that psychological state of the patient at that moment, heart rate, resting state etc. had important effect on this case. Accordingly, skin conductance has been chosen to consider these kinds of cases [9]. In human body, skin response can change according to many psychological and physiologic factors. Besides, the resistance value of almost every part of the body alters depending on the differences of skin nature. If nerves of any part of the body are damaged, it has detected that the resistance value near to the concerning part increases, excessively [10]. Skin thickness has been chosen as the second effective parameter. Skin thickness has the importance of denoting the change of different zones to which the positive electrode contacts. Skin thickness is dependent on the amount of collagen fibres, cellular substances and interstitial fluid content [11]. As a non-invasive technique, ultrasonography has been reported to be very useful for measuring skin thickness, and it has been used in the studies relating skin thickness to age, sex and area of the body [12].

B. Modelling Via ANFIS

ANFIS is an equivalent class of adaptive neural networks to FIS (Fuzzy Inference System) in terms of operation. In this study, the reason of employing ANFIS is its strong modelling ability and providing the optimum model by considering the structure and distribution of the data. In FIS, rules are formed, intuitively by an expert via the handled data. Therefore, it is possible to yield some errors originating from this manual modelling. Because of the mentioned properties of ANFIS, these kinds of errors are eliminated. Fig. 1 denotes the block diagram of the developed model via ANFIS.

III. EXPERIMENTAL RESULTS

The aim of this study is to provide a model for TENS by considering the effective parameters in humans. In other words, the amount of electric current that is applied on human body is attempted to be estimated by handling these parameters. Measurements on the patients have been carried out zone by zone, by considering the ailments which cause pain. As mentioned before, four zones have been chosen for investigation. In accordance with the performed measurements, ANFIS has been employed for modelling. Training and testing results which belong to each implementation zone have been demonstrated in Fig. 2-5. Detailed information (numbers of membership functions and rules, numbers of training and testing data) regarding with the developed model have been indicated in Table 2. As it can be seen in the table, Average Training Error changes between 0.149 - 0.533 while Average Testing Error changes between 0.823 - 1.0815. The value 1.0815 corresponds to a 1.0815mA current swing value in real TENS system. In other words, the current value that is applied to the patient can change in the range of actual value ± 1.0815. The current value that is actual value + 1.0815 does not have any side effects on the nerve fibres and any hampers to obviate the pain. The mentioned situation is viable for the current value that is actual value - 1.0815. But the current value which is actual value + 2 mA disturbs the patient, firstly. Besides, damage of nerve fibres and texture can occur in this case.

IV. CONCLUSION

In this study, modelling of TENS method has been performed. The aims are to provide time saving, minimizing the human originated errors and most importantly, applying TENS efficiently with minimum error on the patients who have communication difficulties. Four implementation zones have been selected by considering the ailments. As the result of performed modelling via ANFIS, Average Training Error changes
between 0.149 - 0.533 while Average Testing Error changes between 0.823 - 1.0815. The value 1.0815 corresponds to a 1.0815mA current swing value in real TENS system. This swing does not have any negative effect on the patient.

This study can be considered as a basis for the more advanced models. By detecting the other effective parameters in humans, the number of input parameters can be increased. Thus, a more sensitive TENS modelling is performed. By increasing the number of output parameters, the effects like frequency and wave modes of TENS can be considered. Accordingly, a more realistic model is performed. Finally, by performing the investigations on more patients, different ailments can be met and this enables us to perform measurements on various zones. Since much more data is obtained in this way, TENS will able to be modelled more sensitively and more close to the real applications.

ACKNOWLEDGEMENTS

We present our thanks to Selcuk University Scientific Research Projects for their financial support and contributions.

REFERENCES