CHARACTERISTIC DIAGRAMS OF ACTIVE AND REACTIVE POWER OF TYPICAL CONSUMERS` GROUPS IN ELECTRODISTRIBUTION ″NOVI SAD″″

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Short summary

This paper focuses on characteristic chronological daily diagrams of active and reactive power (P and Q) in “ED Novi Sad”. The records were registered at different typical groups of consumptions, in the year 2002, 2003 and 2004 during all seasons.
According to the recorded diagrams analysis has been made concerning the behavior of the consumers regarding the consumption of active and reactive energy. The analysis of the mentioned diagrams was done by seasons. It was also tried to approximate the recorded diagrams by the analytical expressions suitable for further calculations.
Also, it was shown what kind of changes, regarding the consumption of electricity, among the consumers happened in the past 10 years.
These diagrams could be an excellent basis to the planners of distribution networks, sector for power system control and distribution system in EPS, load control and finally, market participants for electricity. The consumption of reactive energy in households was especially analyzed because of the better compensation in distribution networks.

1. INTRODUCTION

The households take a great part in a domain of consumption of electricityin electrical distributive consumption field (average household in Srbia consists of 3 or 4 persons and in Vojvodina 3 persons), which in Serbia today is represented by 55% of the load of the total electricity consumption. In typical urban cultures this percentage reaches even 90% of the total consumption. That’s the reason why so much attention is paid to the research of the daily diagrams of the household loads. Herewith, the received metered data is of great interest as an actual basis, with planning development of the distribution network, and with setting the criteria for system control of the same.
The consumers within the category “household” (residential unit with metering) show similar characteristics in regard of the usage of electrical appliances, when they are in similar urban cultures and living facilities especially in regard to food preparation and other basic social needs. That’s why their position is in the group ″household″ which, in those purposes and for the purpose of heating, uses electricity or another type of energy, a so called typical “electrification”.

Also, the further sub grouping has been widened, taking into consideration, apart from “electrification”, also the type of buildings in the settlements, which also affects the load diagrams of the households. In this sense, we make the difference between:

- **individual residential construction**
  - in big cities
  - in small cities
  - in suburbs
  - in villages;

With this type of construction the electricity is being used for food preparation, water heating and sometimes for heating rooms;

- **collective residential construction**
  - city centers, older constructions with partial distance heating and partial heating with electricity, heating the sanitary water and preparing the food using the electricity,
  - new construction with remote heating and water heating and food preparation using the electricity,
  - new construction with remote heating and warm water and food preparation using the electricity,
  - buildings without remote heating, with water heating, food preparation and partial room heating using the electricity.

The division on collective and individual residential construction has been made since the metering has showed that the consumption of electricity at this type of consumers significantly differs. The differences are shown according to room heating of these facilities and water heating as well as food preparation. It is well known that heating in a household could be done by: solid fuel, gas and electricity (heaters, floor heating or thermal accumulating heating) and remote (central) heating from the heating plant, while the food preparation and water heating are mostly done by electricity.

Apart from that, the consumption of energy (electricity or other) for the purpose of heating the households, depends on the quality of building construction especially on insulating material. First of all, from the point of insulation of the outer walls, floors and ceilings of the facilities and then it depends on how many outer or inner walls are outside or inside. It is also significant how the heated water is prepared, either by the heating plants for a number of households or in each household by a boiler. Along with everything said above so far, the number of household members also significantly influences the consumption of electricity, and therefore a household with more than one family living in it with one meter is easily recognized.

In individually constructed residences there are usually more housing areas and there could be a number of electrical appliances which are characteristic in this way of living, for example there could be pumps for watering gardens or grass, mills, manual workshops with electrical appliances (for welding, drilling machines, grinding machines etc.).

The dynamic of consumption of electricity in households of all types of electrification depends on the season, day of the week and hour of the day.

Besides the changes of the active load during time, it is very significant to know the changes of the reactive loads in households. Only the data received by metering could be a relevant basis for the calculation of the compensation of reactive power and energy in the electric power systems.

The knowledge referring to these diagrams, as mentioned, allows good planning and system control of the distribution network.

2. CHOSEN CONSUMS AND METERED DIAGRAMS OF THE LOAD

Recording of the load diagram (active and reactive) was done in two ways. The basic recording of the diagram was at the transformer stations TS X/0,4 kV, which is used by the same types of groups of the consumers. The other “control” recording of the load diagram was done at 6 randomly chosen consumers from the previously chosen groups, and it was used mainly to check the accuracy of the gained results. The daily load diagrams were recorded in 15 minutes intervals.

Four transformer stations in “ED Novi Sad” were chosen for metering. Each transformer station supplies mainly households which are identical in construction and the type of electrification. Along with that, the consumers were chosen from the category household of the collective residential constructions (with remote heating and living intensity, with and without the remote sanitary water heating) and individual (family) residential constructions without the distance heating and a small intensity of living. The difference among them in the sense of electricity consumption was in a way of preparing the hot sanitary water and room heating. The following four types of households were recorded /1/:

- collective construction, (remote heating system + central heating water) 223 consumers in MBTS Western zone 4,
- collective construction, (remote heating system + electrical boilers), 290 consumers in MBTS Neretva,
- individual construction, a half gasified area (partial heating by electricity + partial electrical boilers) 155 consumers in MBTS Koste Racina and
- individual construction, (electrical heating + electrical boilers) 132 consumers in MBTS Zlatariceva.

An average living area of a household in a collective construction could be estimated to 58m^2. This conclusion is based on the data from the heating plant Novi Sad, shown in table 1. The households are mainly with three family members. Similar data gathered for the whole Vojvodina are shown in /2/. This practically means that in the individual constructions, despite the great residential area, in the real function is about 70m^2.
The daily load diagrams of active energy of all mentioned consumption groups are shown in detail in paper /1/.

TABLE 1 – Data of the flats with the remote central heating system in the area of Novi Sad and Petrovaradin

	TO SOUTH	TO EAST	TO NORTH	TO WEST	TO PETROV	TOTAL
Number of flats	19.515	10.095	6.760	17.936	744	55.050
Average flat size	58,9	60	58	55	60	58
Flat consumers (m^2)	1.149.398	605.670	392.071	986.466	44.638	3.178.243
Number of flats with warm sanitary water	7.623			12674		20.297

Data of randomly selected individual "controlled" consumers are shown in table 2 and refer to the consumers from the partial gasified and individual residences.

TABLE 2 – Chosen „control" consumers with an average montly consumption of active and reactive energy in household during summer

No:	**Number of households and description of the structure of consumers:**	Consumption by household	
		(KWh)	(KVArh)
1	**Consumer number 1** – has two households in one facility, of which one household is of three elderly people and the second is of a young couple and two small children, and with an air conditioner,	357	277
2	**Consumer number 2*** - has two households in one facility, of which one household is of three subtenants and the second is of a young couple and two small children	342	120
3	**Consumer number 3*** - is a household of is a young couple and two children	321	130
4	**Consumer number 4* -** is a household with an elderly couple,	257	113
5	**Consumer number 5 -** is a household with a couple and two children	469	202
6	**Consumer number 6** – has two households in one facility, of which one household is of two elderly people and the second is of a young couple and two small children.	395	128

Out of the stated above recordings, the differences in consumption of electricity among the consumers are shown. They are within a framework of the same group of the same amount value. Apart from that, the fact is that each of them consume a significant amount of reactive energy!
Therefore, some more attention will be paid to the diagram of the reactive load.
The most significant consumers of the reactive energy in households are appliances with electric motors or "network" transformers and slugs. The summary of the reactive power of the mostly used electrical appliances in households is shown in picture 1. Their study can be used in choosing those to whom the compensation should be inbuilt at the very beginning of production.

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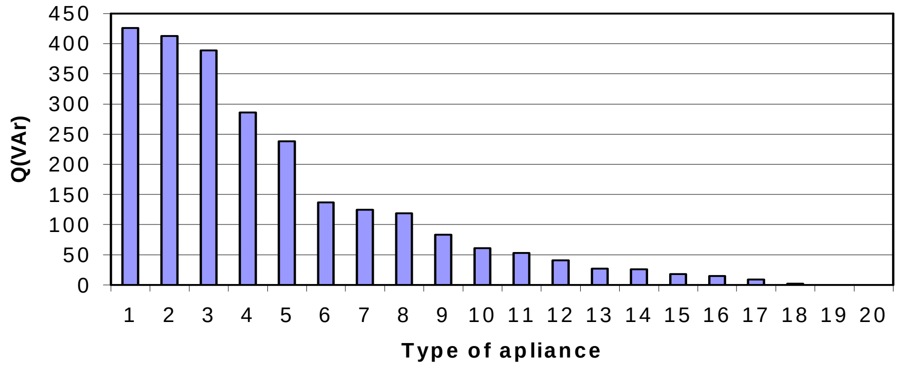
* *Households which use gas*



Type of appliances:

1. Air conditioner (new)
2. Microwave
3. Washing machine
4. Freezer
5. Vacuum cleaner
6. Juicer –minimal load
7. Fridge
8. Air conditioner (old)
9. Fluorescent light bulb
10. Sewing machine
11. Stereo
12. Coffee mill
13. Blender
14. Dishwasher
15. Electric razor
16. Mixer
17. Drill
18. TV – turned on
19. Hair dryer
20. PC

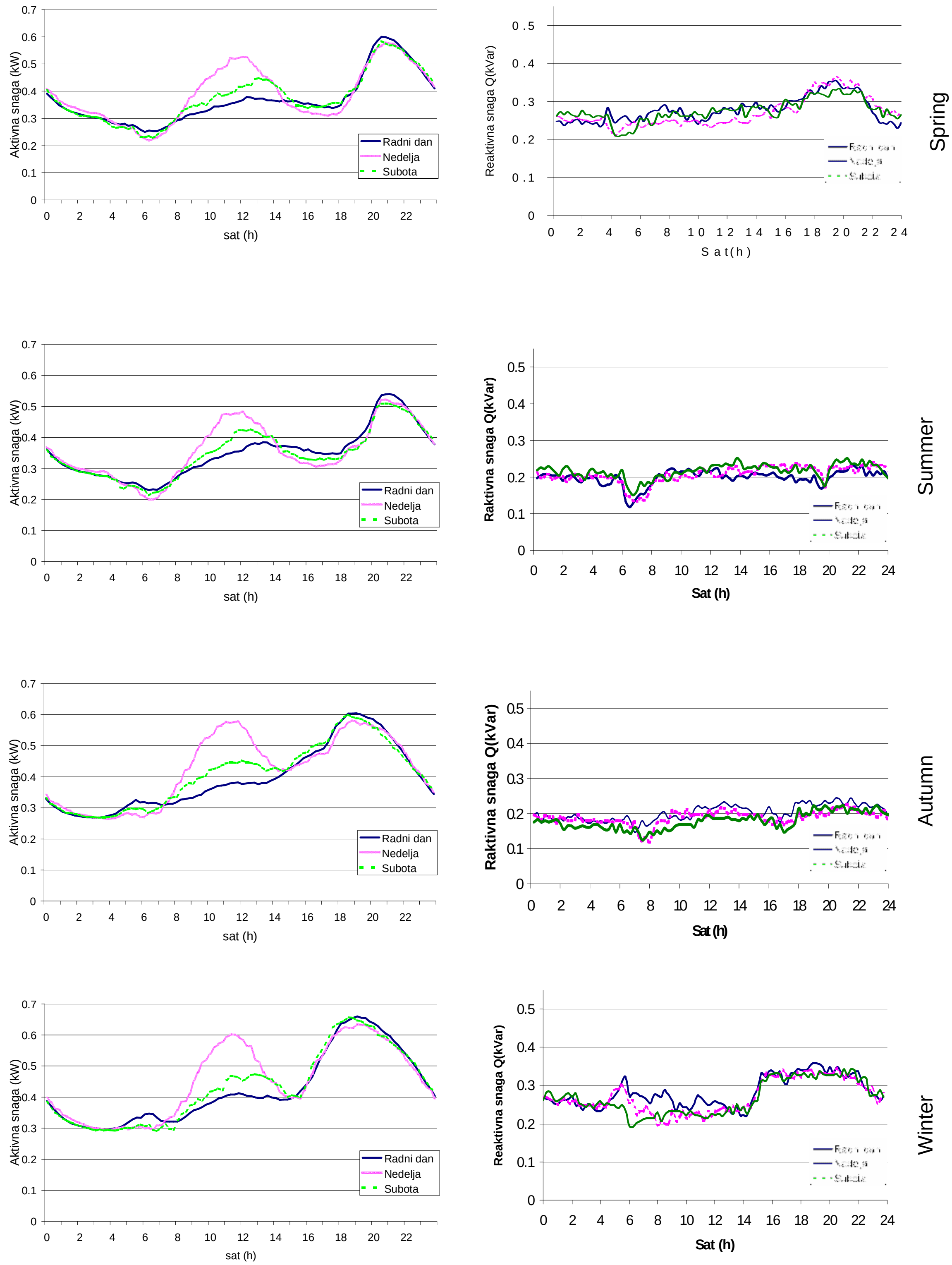
Picture 1 – Diagram of reactive power of electric appliances in a household

For the whole consumption area of "Elektrovojvodina" during: May, June, July, August, and September 2002 and 2003, the consumption of active electricity was nearly constant and had its minimum, while during the winter season was bigger. The reason for that lied in a fact that during those months the consumption of electricity was lowered for the purpose of room heating the.

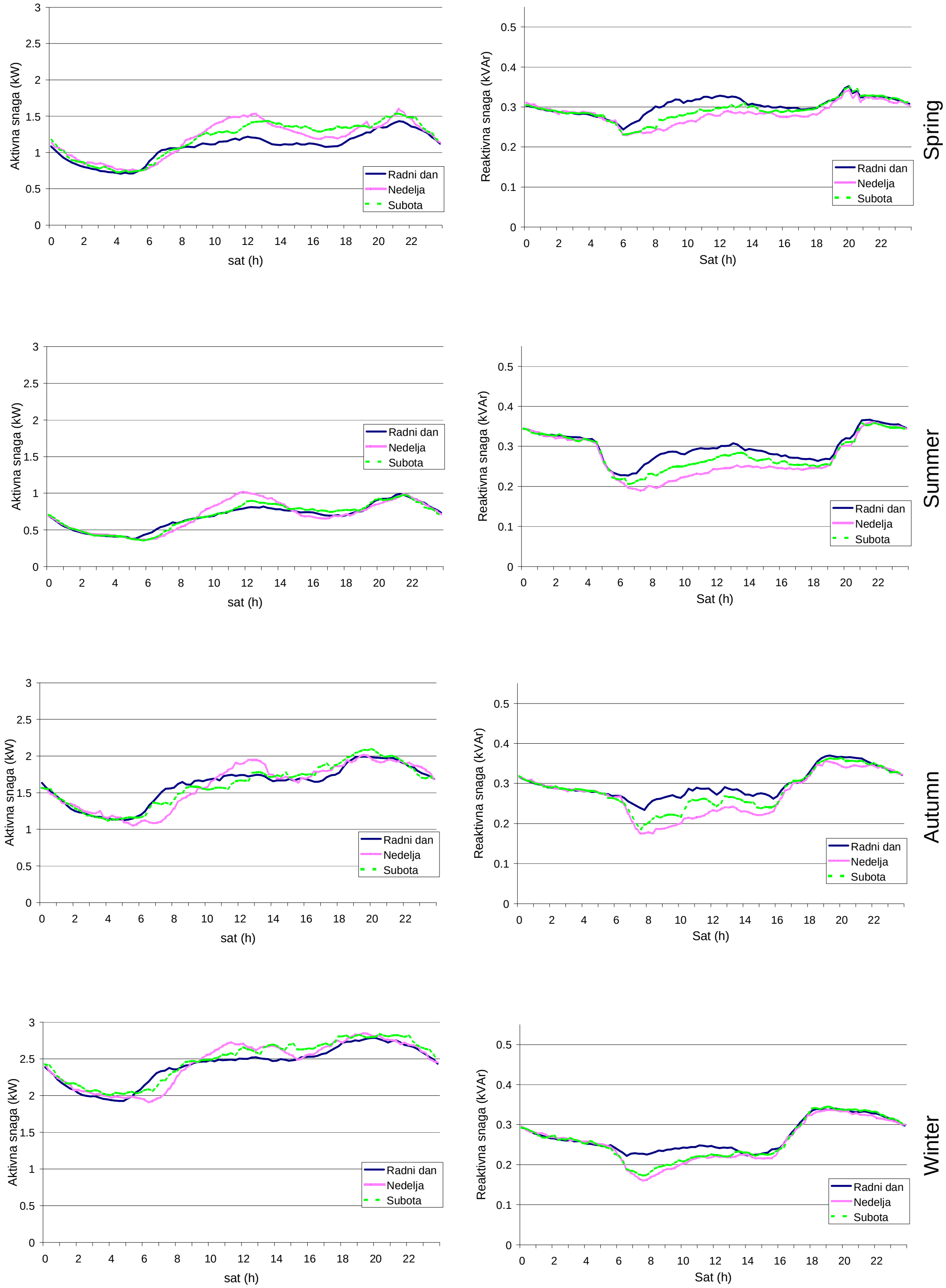
The consumption of reactive energy, for the same consumption area is, however very significant throughout the year and practically constant during the month. During June, July and August there is a small increase of a seasonal reactive energy due to the more intensive food cooling and usege of the air conditioners.

Using the metered records of the mid day active and reactive load according to seasons, the mid day load diagrams were constructed for household and for all working days of the week while the weekend days, Saturdays and Sundays are held separate. Among the recorded diagrams there are significant load differences depending on the season.

Here we will show the daily diagrams of active and reactive power of an average household for some interesting types of constructions and electrifications, according to seasons (pictures 1 and 3), for three characteristic days of the week (working day, Saturday and Sunday) /2/. Having insight at the working day load diagrams it is obvious that they, for the purpose of planning and control, could be shown by only one average daily diagram.



Picture 2 – An average consumer in collective residence with the distance heating sysetm and distance water heating (MBTS West zone 4)



Picture 3 – An average consumer in the individual residence who uses electricity for the purpose of heating and water warming (*MBTS* Zlatarićeva)

3. ANALYSIS OF THE LOAD DIAGRAMS

Based on recorded diagrams, it is obvious that the main differences among them are within the active load, between the periods summer – winter caused by the consumption of electricity for the purpose of room heating and water heating. It should be emphasized that that seasonal difference slowly decreases due to the air conditioner installment. This is especially present at consumers in collective residences in big urban centers. The estimate of the author is that a share of the consumers with air conditioners in the distributive consum is approaching the amount of 15%.
It should also be emphasized that an average **active load** in autumn period is relatively high, which is due to the fact that remote heating and individual winter fuel heating does not follow a subjective need of the consumers to heat the certain rooms of the household mainly with heaters.

The factor of active load $m_P = \dfrac{W}{P_M \cdot 24}$ is within a range of 0,6 – 0,8,

where

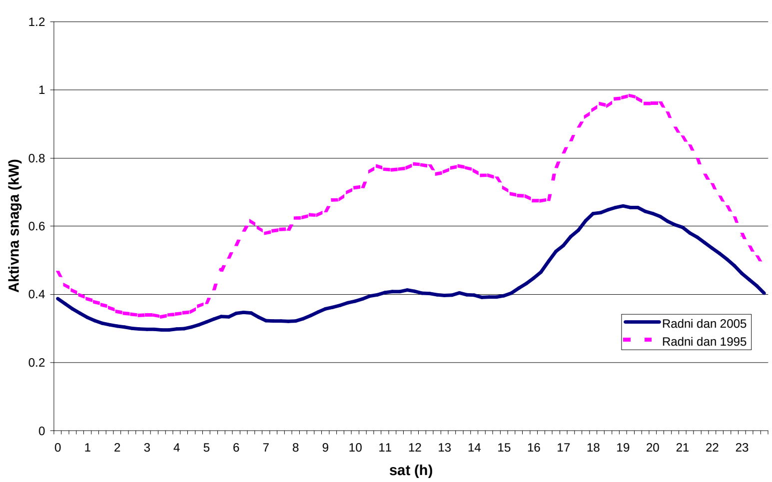
W (kWh) – daily consumed active energy and

P_M (kW) – maximum daily active power.

In summertime , the maximum active load of an average consumer on the level TS SN/0,4 kV does not exceed:

- 0,55 kW at collective residences with remote heating system and hot water, (an average monthly seasonal consumption is 251 kWh),
- 0,7 kW at collective residences with remote heating system and electrical accumulation boilers, (an average monthly seasonal consumption is 343 kWh), and
- 1,0 kW at individual residences with electrical heating and electrical accumulation boilers, (an average monthly seasonal consumption is 491 kWh).
- In winter period, maximal active load of an average consumer of course depends on the way the rooms and water are heated, so the maximum load is:
- 0,65 kW at collective residences with remote heating system and hot water, (an average monthly seasonal consumption is 306 kWh),
- 1,0 kW at collective residences with remote heating system and electrical accumulation boilers (an average monthly seasonal consumption is 529 kWh), and
- 2,8 kW at individual residences with electrical heating and electrical accumulation boilers, (an average monthly seasonal consumption is 1740 kWh).

It is interesting to compare the differences between the daily winter diagrams of active loads of an average consumer for the year 1995 given in /2/ and the same recorded in 2005 which are shown in picture 4. One can see that the shape of a diagram is the same, but an average consumption in 1995 during winter was 471 kWh with an average mid day temperature -3ºC, and in 2005 306 kWh with an average mid day temperature 1,15 ºC, and the reason is the differences of the mid day temperatures and room heating by electricity, as well as a higher no economical general consumption of electricity in 1995 due to dramatically low energy prices in those years.



Picture 4 – Comparing chronological diagrams of residential consumers with remote heating and warm water

An average **reactive load**, considering the working regime and the use of appliances in a household, during the year on the seasonal basis is relatively constant, that is logical.

The diagram of reactive load, of course is not similar to the diagram of active load. Reactive load varies a little during a short period of time as for example a day, week and month. The noticeable variation of reactive load can be noticed only at a seasonal level. In the category consumption – households, these variations are a result of a more intensive use of cooling systems and additional activities of the population in suburbs and villages.

The factor of the reactive load $m_Q = \frac{V}{Q_M \cdot 24}$ is about 0,4,

where:

V (kVArh) – daily consumed reactive energy and

Q_M (kVAr) – maximum daily reactive power.

However, at individual household consumers at suburbs and villages due to various additional activities of different types this factor could vary from 0,2 to 0,9.

Reactive load of an average consumer is a bit different on a daily level, but is dependent on the season of the year and varies between 180 and 400 VAr.

During winter and summer an average is $\approx$300 VAr, with an average monthly consumption of 203 kVArh, and in spring and fall an average is $\approx$200 VAr, with an average monthly consumption of 140 kVArh.

At the individual households at suburbs and villages an average maximum reactive load can reach up to 500 VAr (average monthly consumption is 220 kVArh), due to the already mentioned activities.

Considering the recorded diagrams of reactive loads, consumption characteristics of this energy, these diagrams could be, for the purpose of planning, controll and compensation of reacitve power and energy, well intepolated by a linear function. In that perspective, for example, this function for a reactive load of an average consumer at collective residences with a remote heating system and water for the summer is:

- for working day $Q = 0{,}0009 \cdot t + 0{,}1878$,
- for Saturday $Q = 0{,}0020 \cdot t + 0{,}1822$,
- for Sunday $Q = 0{,}0011 \cdot t + 0{,}2027$,

where Q (kVAr) is reactive power, and t (h) an hour during the day.

Analysis and the results received while applying these expressions at planning an adding of the source of reactive power at the distributive networks at /3/ confirm the correctness of this approach.

4. CONCLUSION

On the basis of the carried out recordings for a longer period of time a contribution has been made at identifying the behavior of the consumers and their characteristics in regard to the daily load diagrams, especially to reactive power or energy. No doubt, they can be used, selectively in respect to the type of construction and the electrification of a household, for all typical consumers` regions throughout Serbia and are good basis for further investigations.

The data of the diagrams versus time of reactive power in the system, even though it is relatively complex to meter for such long period of time and then to systematize, allow the gathering of good results to practically all methodologies for choosing the place of inbuilt and capacity of the compensational devises, that is strategical determination and the sequence of the steps at solving the problems of compensation of reactive power and energy at the distribution networks, that is electric power system. Without the dispute, these results will finally allow the greater quality of the delivery of electricity to the consumers no matter what level of deregulation of electric power industry or its parts is reached.

5. LITERATURE

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Key words: consumption diagram, types of consumers, active energy, reactive energy