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The Effects of Normalization of Static Load Characteristics

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Abstract**-- This paper presents the results of parameter identification of static load characteristics on the basis of large number of field tests. The parameters of most frequently used, polynomial and exponential load model are determined using two different ways of normalization - normalization with voltage and power values just before the voltage change, and normalization with rated voltage and power values. Significant differences between corresponding identified parameter values and predicted power values are found depending on the way of normalization. Better characteristics of normalization with rated voltage and power values are emphasized. This normalization is suggested for power system analyses because another way of normalization causes large parameter deviations and big mistakes in prediction of load values in the examined voltage range, from 0.95 to 1.1p.u.**

Index Terms**-- Distribution system, Measurement based load modelling**

I. Introduction

SINCE load parameters are input data for power system analysis, the accuracy of the calculations are directly dependent on load parameters. Therefore, the subject of many papers is the influence of load parameters on power system stability, e.g. [1] - [4], and load flow solution [5] - [7]. However, determination of valid load characteristics is very difficult task since load composition changes during a day, days of the week and seasons. Also, the characteristics of the load, even of the same load class, can be different in different regions [8], because these are dependent on many factors such are economic, social, climatic etc. Therefore, it is suggestible to identify the load parameters in the region of interest.

Load parameters can be determined using component-based and measurement-based approach [9]. Since the load composition at higher voltage levels is very difficult to obtain, the approach based on measurements seems to be the better one.

Many scientific papers deal with identification of the parameters of load characteristics in real power systems. In most of them the identification is performed on the basis of field measurements obtained during normal operation of power systems or during field tests. Great number of models have been developed depending on load composition, the purpose of load modelling and wonted accuracy [4], [10] - [14].

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In last years, there are increasing research efforts to determine valid load parameters. For example, in [15] are identified load parameters of several load models on the basis of large number of measurements during power system disturbances. In this paper, the adequacy of using static load models for transient stability analysis is examined for various loading conditions. References [8] and [16] present the results of load model parameter identification on the basis of over hundred experiments in medium voltage network. The results of parameter identification using data recorded during several years and complex mathematic procedures are presented in [17].

Very important issue of load modeling is the normalization of load characteristics, since inappropriate normalization can cause wrong, even absurd results. For example, in [12] it is suggested to normalize reactive power with initial real power, P_0, instead of initial reactive power, Q_0, to avoid problems in the case where Q_0 is zero due to cancellation of the load reactive consumption and reactive losses by shunt capacitance.

Normalization of reactive power with apparent power, S_0, is suggested in [18] where exponential dynamic load model is used for load modeling. It is shown that normalization with Q_0 that is close to zero yields very large deviation in identified parameters β_s and β_t, i.e. unrealistic large negative and positive values. Therefore this normalization is inappropriate. The variability in the parameters is drastically reduced by using initial apparent power for normalization. Unreliability of exponential load model used for aggregate loads at high voltage busses with power factor correcting devices is proven in [19]. It is suggested to model real and apparent power instead of real and reactive power, because variation of the apparent power voltage exponent with voltage is quite small compared to that of the reactive power voltage exponent.

However, there are two substantially different ways of normalization of load characteristics that are almost equally used in literature, but have not been mutually compared by now. Also, their consequences on identified parameters and predicted power values are not discussed in any of scientific papers or books. These are normalization with initial voltage and initial real and reactive (or apparent) power values (V_0, P_0, Q_0) used for example in [9], [12] and [13], and normalization with rated voltage and rated real and reactive power values (V_n, P_n and Q_n) applied in many papers such are [11], [14], [20] and [21].

Therefore, the aim of this paper is to answer the questions like the following ones: which one of these two ways of normalization is more suitable for consideration of the load under different operating conditions, is there any difference between corresponding load model parameters obtained on the basis of two ways of normalization and, if yes, what are their consequences on load values? The answers are made on the basis of the parameters of most frequently used static load models obtained from large number of field tests.

II. Most Frequently Used Static Load Models

Static load models describe real and reactive power dependence on voltage and frequency. Many static load models have been developed by now and most of them are presented in [10]. Very frequently used static load models are exponential and polynomial model and their variants [9] - [14], [19] - [22]. In many cases, however, the frequency dependence is neglected due to relatively narrow range of frequency variation. Therefore, the most frequently used static load models are polynomial

$$P = P_n\left(p_1\left(\frac{V}{V_n}\right)^2 + p_2\frac{V}{V_n} + p_3\right), \quad (1)$$

$$Q = Q_n\left(q_1\left(\frac{V}{V_n}\right)^2 + q_2\frac{V}{V_n} + q_3\right) \quad (2)$$

and exponential model

$$P = P_n\left(\frac{V}{V_n}\right)^{k_{pv}}, \quad (3)$$

$$Q = Q_n\left(\frac{V}{V_n}\right)^{k_{qv}}. \quad (4)$$

Polynomial model (1)-(2) is also called *ZIP* model since it consists of constant impedance (*Z*), constant current (*I*) and constant power (*P*) load component. In this model P_n and Q_n are real and reactive power at rated voltage V_n. Parameters p_1 and q_1 represent relative participation of constant impedance load, p_2 and q_2 relative participation of constant current load and p_3 and q_3 relative participation of constant power load in total load.

Exponential model (3)-(4) is even more frequently used than polynomial model, especially in power system stability analyses. This model features parameters k_{pv} and k_{qv} that represent the derivatives of real and reactive power with respect to voltage in the vicinity of V_n [10].

There are alternative forms of previous models that are very frequently used, too. These forms use initial real and reactive power, P_0 and Q_0 respectively, at initial voltage, V_0 ([9], [12], [13]) instead of rated power and voltage values (P_n, Q_n and V_n).

III. Field Tests

Data for parameter identification were obtained from field tests that comprehended manual changes of transformer turns ratio that caused secondary voltage changes. During the tests secondary voltage of transformer T_1 110/35kV in TS "Niš 13" that supplies predominantly residential load varied in relatively wide ranges, from 0.95 to 1.1p.u. Effective (rms) voltage values, real and reactive power were measured by digital data acquisition device (Chauvin Arnoux C. A 8332). The device was connected to existing current (CT) and voltage transformers (VT) according to simplified experimental schema from Fig. 1.

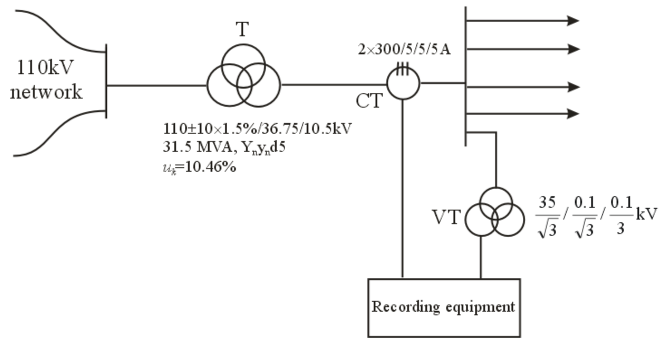

Fig. 1. Simplified experimental schema.

Even 68 experiments of voltage changes were performed during one working day, Saturday and Sunday, in the period from 30th September to 2nd October 2005, in three day periods - morning, afternoon and night. The voltage changed up and down for different rates. Therefore, the operation conditions during the tests were quite different and the question arises how to compare the results of all these experiments? Firstly, it is necessary it normalize the measured data in one of mentioned ways - with initial or rated voltage and power values.

Considering the variability of operating conditions and voltage changes, it is reasonable to select the normalization of measured data with network rated voltage (and power values that correspond to this voltage) because this voltage is common to all operating conditions. In this way static load characteristics, obtained from experiments with different initial and different final voltage values, become mutually comparable.

IV. The Effects of Normalization

A. Deviation of Identified Load Model Parameters

This Subsection presents the results of the analysis regarding the influence of normalization on identified load model parameters.

This influence is illustrated on the example of two experiments performed on Sunday when the load composition can regard to be the same [16]. During these two experiments secondary voltage of transformer T_1 changed for similar absolute values. The first experiment caused the decrease of voltage from 36.6 to 34.17kV, and the second one the voltage increase from 34.33 to 37.2kV. Measured voltage and reactive power values during these experiments and corresponding polynomial fits, obtained by least square method [23], are presented in Figs. 2a) and 2b), respectively. Polynomial fits from these figures:

$$Q(V) = 163.3476 - 9.77914 \cdot V + 0.1506 \cdot V^2 \quad (5)$$

and

$$Q(V) = 139.1725 - 8.41907 \cdot V + 0.13121 \cdot V^2, \qquad (6)$$

where V is in kV and Q is in MVAr, represent reactive power-voltage dependences with very large correlation coefficients [23], R>0.99.

Large correlation coefficients, R>0.9, are also obtained for other 66 polynomial fits of power-voltage relationships during experiments of voltage changes. Maximum deviations of measured values from these fittings do not exceed 1% that confirms high quality of these fits.

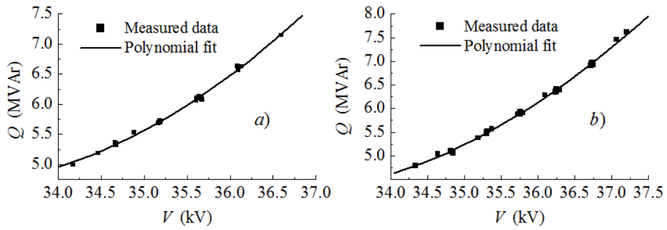

Fig. 2. Measured values and polynomial fit from the experiment of: voltage decrease a) and voltage increase b).

The normalization of measured values from Figs 2a) and 2b) with rated voltage and power values imply dividing of measured data with V_n =35kV and with Q_n obtained from polynomial fit (5) and (6) by substitution of V_n. Then, fitting of these normalized values with polynomials, using least square method, yields static characteristics:

$$Q(V) = 29.3647 - 61.5292 \cdot V + 33.1651 \cdot V^2 \qquad (7)$$

and

$$Q(V) = 26.5731 - 56.2628 \cdot V + 30.6900 \cdot V^2, \qquad (8)$$

for the experiments of voltage decrease and voltage increase, respectively. In (7) and (8) Q and V are in p.u. Corresponding parameters from these two characteristics differ from each other for less than 10%.

On the other hand, the normalization of measured values from Figs. 2a) and 2b) with initial voltage and power values comprehends their dividing with V_0=36.6kV and Q_0=7.149MVAr for the experiment of voltage decrease and dividing with V_0=34.33kV and Q_0=4.791MVAr for the experiment of voltage increase. Polynomial fits of measured values normalized in this ways, are:

$$Q(V) = 22.8473 - 50.0591 \cdot V + 28.2148 \cdot V^2 \qquad (9)$$

and

$$Q(V) = 29.0482 - 60.3346 \cdot V + 32.2857 \cdot V^2, \qquad (10)$$

for the experiment of voltage decrease and voltage increase, respectively. In both static characteristics Q and V are in p.u. These characteristics describe power-voltage relationships equally well as in the case of normalization with V_n and Q_n, since R>0.99. However, the differences between corresponding parameters in polynomial models (9) and (10) are much greater, up to 27%.

Besides the differences in polynomial model parameters, the normalization with initial voltage and power values can cause significant differences in parameter values of other models, and therefore big errors in power estimation. This is presented on the example of another very frequently used static load model - exponential one.

According to definitions of exponential load model parameters [22], these are:

$$k_{pv} = dP/dV\big|_{V=1} \qquad (11)$$

for real and

$$k_{qv} = dQ/dV\big|_{V=1} \qquad (12)$$

for reactive power. Since polynomial model describes power-voltage relationships of examined load very well, parameters k_{pv} and k_{qv} can be obtained from polynomial characteristics, using (11) and (12).

Thus, in the case when polynomial reactive power characteristics are normalized with initial voltage and power values, k_{qv}=6.370 is obtained for the experiment of voltage decrease and k_{qv}=4.237 for the experiment of voltage increase. Exponential characteristics with these parameters together with normalized measured data and adequate polynomial fits are presented in Figs. 3a) and 3b). The analysis of reactive power values obtained using exponential model shows that maximum deviations from measured data are 7.4% for the experiment of voltage decrease and 11.6% for voltage increase.

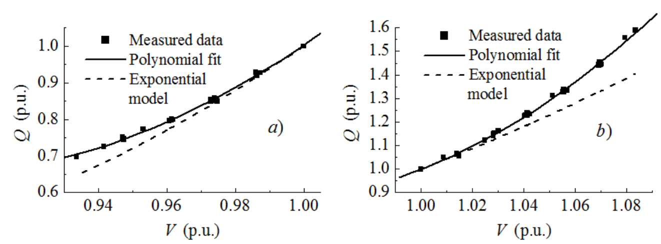

Fig. 3. Measured data normalized with V_0 and Q_0, polynomial fit and exponential model for: voltage decrease a), and voltage increase b).

Likewise, polynomial characteristics that are normalized with V_n and Q_n, can be used for parameter determination of exponential characteristics. In this case, from (7) $k_{qu} = dQ/dU\big|_{U=1} = 4.801$ and from (8) $k_{qu} = 5.117$. These parameters are much closer to each other than the parameters obtained on the basis of normalization with initial voltage and power values from the same experiments.

Furthermore, exponential characteristics with parameters k_{qu}=4.801 and k_{qu}=5.117 yield smaller deviations of reactive power from measured data that were in the case of exponential characteristics obtained using normalization with initial voltage and power values (see Fig. 4).

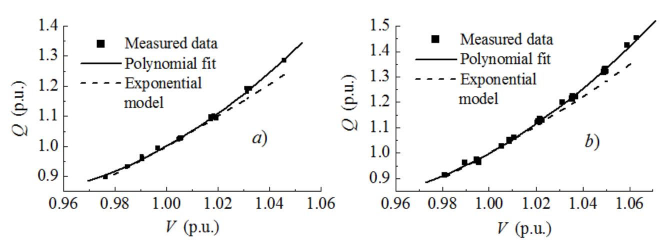

Fig. 4. Measured data normalized with V_n and Q_n, polynomial fit and exponential model for: voltage decrease a), and increase b).

The analysis of these deviations - errors in prediction of power values shows that maximum errors are 3.6 and 6% for the experiment of voltage decrease and voltage increase, respectively. These errors are approximately two times smaller than the errors obtained when normalization with V_n and Q_n is used.

Since even 68 experiments were performed, the parameters of exponential load model obtained from all experiments on the basis of both ways of normalization are statistically analysed. The overview of data regarding statistical analysis of exponential model parameters of reactive and real power is presented in Table I. It comprehends k_{qv} and k_{pv} mean values, their standard deviations, minimum, maximum values and the ranges of identified parameter values for both ways of normalization.

According to data from Table I, in the case of normalization with V_0 and Q_0 minimum and maximum values of k_{qv} are 2.726 and 7.016, respectively, i.e. the range of identified values is even 4.291, that is somewhat less than k_{qv} mean value (4.983). In the case of normalization with V_n and Q_n the range of k_{qv} is 2.085, that is approximately two times smaller than previously mentioned range. Besides, standard deviation, σ, in the case of normalization with initial voltage and power values is even 171.54% larger than that obtained using normalization with rated voltage and power values. It means that there is significant difference in parameter dissipation between two ways of normalization.

Similar conclusions can be made for the parameter k_{pv}. When normalization with initial voltage and initial real power values is used, k_{pv} belongs to wider range (1.197÷1.912) in comparison with the values obtained on the basis of another way of normalization (1.320÷1.783). The range of k_{pv} is 45.40% of the mean value when V_0 and P_0 are used for normalization, but significantly smaller, 29.87% of corresponding mean value, when normalization with V_n and P_n is used.

TABLE I

MEAN VALUES, STANDARD DEVIATIONS, MINIMUM, MAXIMUM VALUES AND THE RANGES OF k_{qv} AND k_{pv} FOR DIFFERENT NORMALIZATIONS

Parameter	Normalization quantities	Mean	σ	Min	Max	Range
k_{qv}	V_0, Q_0	4.983	1.040	2.726	7.016	4.291
	V_n, Q_n	4.880	0.383	3.680	5.765	2.085
k_{pv}	V_0, P_0	1.577	0.138	1.197	1.912	0.716
	V_n, P_n	1.550	0.099	1.320	1.783	0.463

Further analysis of deviations of exponential model parameters is made on the basis of histograms of k_{qv} and k_{pv} probabilities in Figs. 5 and 6, respectively, obtained using normalization with initial voltage and power values, and normalization with rated voltage and power values. Fig. 5a) demonstrates very large dissipation of k_{qv} values when V_0 and Q_0 are used for normalization, and Fig. 5b) notable smaller range of this parameter obtained owing to normalization with V_n and Q_n. Histogram of probability from Fig. 5b) can be approximated with Gauss, normal distribution with very good correlation, R=0.973. On the basis of this distribution with 95.5% probability it can be written

$$k_{qv} = \mu_{k_{qv}} \pm 2\sigma_{k_{qv}} = 4.908 \pm 0.584 \ . \tag{13}$$

Center of probability, $\mu_{k_{qv}}$ is almost equal to mean parameter value from Table I obtained using corresponding way of normalization.

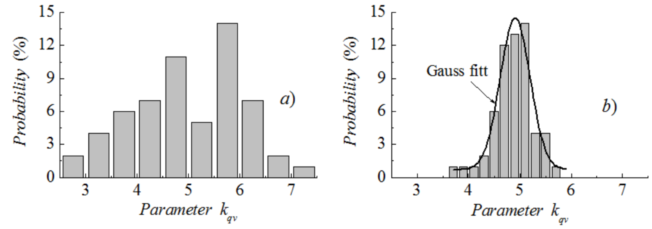

Fig. 5. Probabilities of k_{qv} obtained using normalization with: V_0 and Q_0 a), and V_n and Q_n b).

Figs. 6a) and 6b) present histograms of k_{pv} probabilities obtained using normalization with V_0 and P_0, and with V_n and P_n, respectively. Approximation of these histograms with Gauss distributions is possible with large correlation coefficients, R=0.909 and R=0.943, for Figs. 6a) and 6b), respectively. According to these Gauss distributions, with 95.5% probabilities it can be written

$$k_{pv} = \mu_{k\,pv} \pm 2\sigma_{k\,pv} = 1.533 \pm 0.173 \tag{14}$$

in the case of normalization with V_0 and P_0, and

$$k_{pv} = \mu_{k\,pv} \pm 2\sigma_{k\,pv} = 1.547 \pm 0.153 \tag{15}$$

in the case of normalization with V_n and P_n. Centers of probabilities from (14) and (15) differ from each other at second decimal place, but the values obtained using normalization with V_0 and P_0 belong to the wider range.

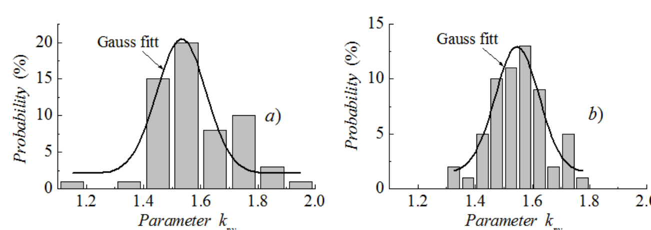

Fig. 6. Probabilities of k_{pv} obtained using normalization with: V_0 and Q_0 a), and V_n and Q_n b).

B. Errors in Prediction of Power Values

As demonstrated in Subsection IV.A on the example of two experiments - experiment of voltage decrease and voltage increase, the exponential model obtained on the basis of polynomial characteristic normalized with rated voltage and power values yield smaller error in prediction of power values. However, these errors depend on the range of the voltage change - its initial and final value during the experiment and the shape of power-voltage characteristic of examined load.

Voltage changes during all performed experiments were of similar absolute value (≈0.75p.u.) but for different initial and final values that belong to relatively wide range, from 0.95p.u. to 1.1p.u. Therefore, here are presented results of statistical analysis of maximum errors in prediction of power values when exponential load model is used for modelling of the load normalized with initial and with rated voltage and power values.

Probabilities of maximum errors in prediction of reactive power values when normalization with V_0 and Q_0 and normalization with V_n and Q_n are used are presented in Figs. 7a) and 7b), respectively. It is obvious that normalization with initial voltage and power values yields errors that belong to wider range (from 0.50% to 22.2%) in comparison with the range (from 0.40% to 14.45%) when rated voltage and power values are used. Furthermore, average value of maximum errors as a consequence of normalization with V_0 and Q_0 is 6.45% and it is almost two times larger in comparison with the average value of maximum errors obtained owing to the normalization with V_n and Q_n that is 3.57%. Besides, the values of the errors obtained with 95% cumulative probability are below 15.86% and 8.46% for normalization with initial and rated voltage and power values, respectively.

Similar conclusions regarding smaller errors in prediction of power values and regarding the ranges of these errors for two ways of normalization can be made for real power, too. However, since real power characteristics of examined load are almost linear [16], errors due to the modelling with exponential characteristics are much smaller. Thus, average value of maximum errors in prediction of power values, when V_0 and P_0 are used, is 0.81%, while in the case of normalization with V_n and P_n this error is only 0.43%. Maximum value of all errors is also small and it does not exceed 3.38% and 1.10% in the case of normalization with V_0 and P_0 and with V_n and P_n, respectively.

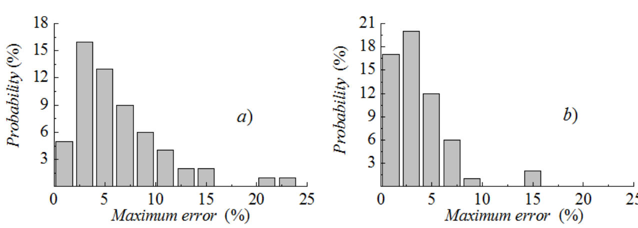

Fig. 7. Probabilities of maximum errors in prediction of power values obtained using normalization with: V_0 and Q_0 a), and V_n and Q_n b).

V. Conclusion

The paper discusses the effects of normalization of static load characteristics on the basis of large number of experiments of voltage changes from 0.95 to 1.1p.u. in medium voltage distribution network. The comparison of two commonly used ways of normalization - with initial voltage and power values and rated voltage and power values yields some important and very useful conclusions.

In the case when static characteristics from different loading conditions should be mutually compared, the normalization of measured data with rated voltage and corresponding (rated) real and reactive power values is suggested since network rated voltage is common to every operation condition. Identified polynomial and exponential load model parameters obtained on the basis of normalization with rated voltage and power values belong to significantly narrower ranges in comparison with corresponding parameters obtained after the normalization with initial voltage and power values. For example, the range of all identified parameter k_{qu} values of examined load is 2.085 in the case of the former normalization, but even more than two times larger (4.291) in the case of the latter. Errors in prediction of power values obtained by the most frequently used static model in stability analyses, exponential model, are smaller when normalization with rated voltage and power values are used. It especially concerns reactive power of examined load where average value of maximum errors decrease from 6.45% to 3.57% for normalization with initial and rated voltage and power values, respectively.

Regarding the mentioned facts, the authors suggest to use the normalization of static load characteristics with rated voltage and power values as the better one.

VI. Acknowledgment

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VII. References

[1] D. L. H. Aik, and G. Andersson, "Influence of Load Characteristics on the Power/Voltage Stability of HVDC Systems, Part 1: Basic Equations and Relationships," *IEEE Trans. Power Delivery*, vol. 13, pp. 1437-1444, Oct. 1998.

[2] M. K. Pal, "Voltage Stability Conditions Considering Load Characteristics," *IEEE Trans. Power Systems*, vol. 7, pp. 243-249, Feb. 1992.

[3] A. Borghetti, R. Caldon, A. Mari, and C. Nucci, "On Dynamic Load Models for Voltage Stability Studies, " *IEEE Trans. Power Systems*, vol. 12, pp. 293-303, Feb. 1997.

[4] W. S. Kao, C.-T. Huang, and C.-Y. Chiou, "Dynamic Load Modeling in Taipower System Stability Studies," *IEEE Trans. Power Systems*, vol. 10, pp. 907-914, Aug. 1995.

[5] A. Losi, and M. Russo, "Load modeling impact on object oriented distribution load flow," in *Proc. 2003 IEEE Power Tech Conf.*, pp. 1-6.

[6] M. H. Haque, "Load flow solution of distribution systems with voltage dependent load models," *Electric Power Systems Research*, vol. 36, pp. 151-156, Mar. 1996.

[7] D. Stojanović, and L. Korunović, "The Analysis of Load Types Influence on Distribution Network Calculation Results," *Elektroprivreda*, pp. 76-81. Jan.-Feb. 2000. (in Serbian)

[8] L. Korunović, D. Stojanović, and J. V. Milanović, "Identification of Static Load Characteristics Based on Measurements in Medium-Voltage Distribution Network," *IET Gen. Transm. Distrib.*, vol. 2, pp. 227-234, Mar. 2008.

[9] P. Kundur, *Power System Stability and Control*, New York: Mc Graw-Hill, 1994.

[10] IEEE Task Force on Load Representation for Dynamic Performance, "Bibliography on Load Models for Power Flow and Dynamic Performance Simulation," *IEEE Trans. Power Systems*, Vol. 10, pp. 523-538, Feb. 1995.

[11] T. Frantz, T. Gentile, S. Ihara, N. Simons, and M. Waldron, "Load Behavior Observed in LILCO and RG&E Systems," *IEEE Trans. Power App. Syst.*, vol. PAS-103, pp. 819-831, Apr. 1984.

[12] W. W. Price, K. A. Wirgau, A. Murdoch, J. Mitsche, E. Vaahedi, and M. A. El-Kady, "Load Modeling for Power Flow and Transient Stability Computer Studies," *IEEE Trans. Power Systems*, vol. 3, pp. 180-187, Feb. 1988.

[13] Y. Baghzouz, and C. Quist, "Determination of Static Load Models from LTC and Capacitor Switching Tests," in *Proc. 2000 IEEE Power Engineering Society Summer Meeting,* pp. 389-394.

[14] Y. Baghzouz, and C. Quist, "Composite Load Model Derivation from Recorded Field Data," in *Proc. 1999 IEEE Power Engineering Society Winter Meeting,* pp. 713–718.

[15] Y. Li, H.-D. Chiang, B.-K. Choi, Y.-T. Chen, D.-H. Huang, and M. G. Lauby, "Representative static load models for transient stability analysis: development and examination," *IET Gen. Transm. Distrib.*, vol. 1, pp. 422 - 431, May 2007.

[16] L. Korunović, and D. Stojanović, "Static Load Characteristics on 35kV Level of Distribution Network of Nis," *Elektroprivreda*, pp. 64-71, Oct.-Dec. 2008. (in Serbian)

[17] H. Renmu, M. Jin, and D. J. Hill, "Composite Load Modeling via Measurement Approach," *IEEE Trans. Power Systems*, vol. 21, pp. 663-672, May 2006.

[18] I. R. Navarro, O. Samuelsson, and S. Lindahl, "Influence of Normalization in Dynamic Reactive Load Models," *IEEE Trans. Power Systems*, vol. 18, pp. 972-973, May 2003.

[19] J. Milanović, "On unreliability of exponential load models," *Electric Power System Research*, Vol. 49, pp. 1-9, Feb. 1999.

[20] J. Ribeiro, and F. Lange, "A New Aggregation Method for Determining Composite Load Characteristics," *IEEE Trans. Power App. Syst.*, vol. PAS-101, pp. 2869-2875, Aug. 1982.

[21] L. M. Hajagos, and B. Danai, "Laboratory Measurements and Models of Modern Loads and Their Effect on Voltage Stability Studies," *IEEE Trans. Power Systems*, vol. 13, pp. 584-592, May 1998.

[22] C. Taylor, *Power System Voltage Stability*, New York: Mc Graw-Hill, 1994.

[23] M. Merkle, "Probability and statistics for engineers and students of technical sciences," Belgrade: Akademska misao, 2006. (in Serbian)

VIII. Biographies

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