VERIFICATION OF THE STATE ESTIMATION FUNCTION IN ED SOMBOR

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ABSTRACT

This paper presents results of application of functions of state estimation in the distribution network of Distribution utility Elektrovojvodina, Division ED Sombor. Expected limits of quality are defined, both estimation of state on supply transformer (ST 1) high/medium voltage (HV/MV) and MV feeder, and estimation of load supply substation (SS) 20/0,4 kV/kV. At the same time the paper points out a possibility of improvement of quality of results of estimation of state, by system improvement of quality of historic data with which consumption of distributive network has been described. At the end of the paper it is shown that state estimation in real time is not only possible but sufficiently reliable and accurate for operating distributive networks. Verification of results of the function of estimation of state obtained in on-line mode was done on basis of simultaneously measured values in the system.

1. INTRODUCTION

The estimation of state presents a basic analytic function on whose/which basis almost all other functions for analysis, operation management and operation planning of medium voltage distribution networks (MV DN) are based on: regulation of voltage reconfiguration under load, dispatching, failures in the network, optimal network configuration, restoration of supply, relay protection, etc. (1,2). Subsequently the quality of business of distribution depends on the quality of its results: the quality of delivered electrical energy, management of consumption, reduction of losses, decrease of number of faults, planning of distribution network development, better utilization of existing energy objects, postponing of investments, etc.

Usually modest remote monitoring of DNs referring to transmission ones is the key difference in the management of both networks. A distribution Supervisory Control and Data Acquisition (SCADA) system usually covers only SS and a small numbers of MV points. Thus, the redundancy of real-time telemetered data in DNs is significantly smaller than 1.0 (it amounts about 0.2 – 0.3 (1)). Nevertheless, there are a large number of attempts to transfer and adopt the estimation algorithms from the transmission into the distribution environment (3-6). These attempts do not have high chance for success for the noted small distribution data redundancy. That is why new specialized algorithms for distribution state estimation have been developing in the last ten years (2, 7 i 8). Nevertheless, there is no reference that establishes a standard state estimation procedure and proves it in the distribution network practice.

A simple, fast and robust Real-Time Distribution State Estimator (DSE) is briefly described in Section 2 (9). It represents a compromise between complex methods proposed in the literature and the usually available data in distribution utilities. The developed DSE can be applied in any distribution utility – with or without installed

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SCADA system, in both the on-line (real-time) and off-line mode. The mentioned DSE model is integrated in the software package of energy applications for operational management DN (10) which was installed in ED Sombor in 2001.
The results of application of DSE in real DN are shown in the third part of the paper. Verification of the quality of the result was done on basis of application of comparison of results of estimated and simultaneously measured values. The crucial conclusion is derived in Section 4: the state estimation in DNs is not only possible, but also sufficiently reliable and accurate for the purpose of real-time managing of DNs. References used for writing this paper are listed in Section 5

2. DISTRIBUTION STATE ESTIMATION

DSE algorithm consists of the following five steps (11): 1 – Pre-estimation, 2 – Topology Verification, 3 – Measurements Verification, 4 – Load Calibration and 5 – Load Flow Calculation.

2.1 Pre-estimation

Historical data which illustrate consumption by the consumers of DN, can be divided into two groups:

- *dimensionless daily load profiles (DLP)* – current magnitude and power factor, Fig. 1, i.e. of active and reactive power, for each of characteristic days (e.g. work day, Saturday, Sunday and holiday) and each of characteristic periods (for example spring, summer, autumn, winter) an,
- *quantifiers of consumption* – can be the values: reading of maximal currents (loads) (in A, kW, kVAR),reading of flow of supplied energies (in kWh, kVARh) for each characteristic period, that is rated powers of the transformers (in kVA)[1].

Result of multiplication of DLP of current (power) and corresponding value of consumption quantifiers presents daily load curves (DLCs) of consumption of the observed user in adequate units. The consumption values of the consumers for the observed moment (taken from the DLCs) present pre-estimated values of consumption.
Pre-estimated regime is obtained on basis of calculation of load flow (12) for the given voltage of the root, known topology of the network and pre-estimated values of consumption. If telemetered values of measurements are also available (collected by SCADA System) the next step is taken of the DSE algorithm, otherwise pre-estimation of the regime presents its final step, and the pre-estimated regime its final result.

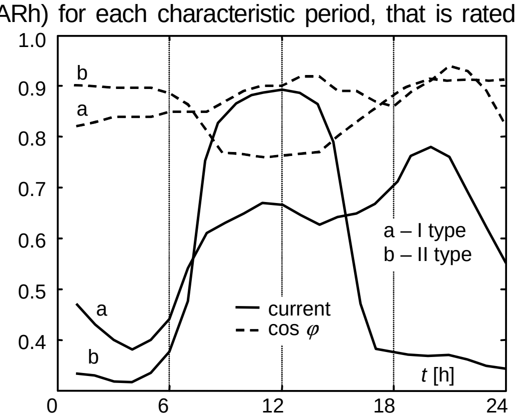

Figure 1 – DLP of consumption for two types of consumption

2.2. Verification of topological structure

Verification of the topological structure represents a test of actual topological structure of DN, in other words finding and elimination of possibly made mistakes that occurred when updating the change of status of switchgear of DN that are done by the SCADA System and/or manually in the field. Due to extremely small redundancy remotely transferred data, possibilities of this part of algorithm are very modest but not valueless. The activities are reduced to keeping record of changes of measured values. These heuristic rules are based on the fact that the value of consumption constantly changes. If DSE is done constantly (for example every 10 seconds) each sudden change of telemetered measured value, that is not being observed by the change of status of switchgear, i.e. a great difference between „good“ historical data and telemetered values, is a consequence of inaccurate network topology, i.e. is considered „bad“ telemetered measured value.

2.3. Verification of telemetered measurement values

Verification of measurements means detection, correction, or elimination of bad telemetered measurement values. Due to small data redundancy, verification of measurement is based on artificial redundancy of data, that is achieved by pseudo and virtual measurements that are the result of pre- estimation of the regime. Verification of telemetered measurement values consists of the following five sub-steps (13):
<u>1. Preparation of measurements:</u> Transformation of all measurements, of various nature (power, current and power factor) the same measurements: 1) current magnitudes and power factors or 2) active and reactive

[1] Previous experience with the state estimation show that the worst results are obtained when values of installed transformer power are used as quantitative indicators.

power. 2. Elimination of obviously bad measurements: Obviously bad measurement is the measurement whose value: outside of limits imposed by relay protection; zero, but consumption exists downstream; exceeds the pre-specified difference from its pre-estimated values, etc. These measurements are excluded from the following steps of DSE algorithm. 3. Reduction of network: The network is reduced by equivalenting of all non-observable parts – areas. The area consists of all electrically connected elements (line section, transformer stations, etc.) without telemetered values of measurements of current (power). The area is connected with outer external network solely by branches with telemetered measurements. Thus, the islands are not observable in detail, but their total consumption is. In this way, after application of a very simple procedure of equivalenting, the pre-dominant non-observable network with N buses (Fig. 2) is reduced into a totally observable equivalent network with N_o buses (Fig. 2b, islands are marked by a dashed line). 4. Procedure of verification. Optimization procedure with limitations for verification of measurement, applied onto the observable equivalent network model (with reduced number of buses) is radically faster than application onto the model of the entire network. This procedure consists of minimization of the objective function – the sum of square of difference between measured (m) and pre-estimated (e) values N_m of telemetered measurements x_j and N_o of total consumption of the islands x_n:

$$\Phi = \sum_{j=1}^{N_m} [w_j^m (x_j^m - x_j^e)^2 + w_j^p (x_j^p - x_j^e)^2] W_j + \sum_{n=1}^{N_o} w_n^p (x_n^p - x_n^e)^2] W_n , \quad (1)$$

with N_o limitations, one limitation for each area:

$$f_n = x_n^e + \Delta x_n^p - \sum_{j=1}^{N_m} k_{nj} x_j^e = 0 , \qquad n=1, \dots N_o . \quad (2)$$

Relative weights of telemetered and pre-estimated values are marked with w; and relative weights of variables of state and islands' consumption with W; k_{nj} stands for the marking of the measured value x_j (positive if it enters into the area); Δx_n stands for total active and reactive losses, when the variables x_j are unknown in (1) of active and reactive powers, i.e. real and imaginary part of total island current of the islands when variables of current are unknown. Equations of power flow are the main limitations of this optimization procedure. Implicitly they are included in the procedure via the first and the fifth step: Pre-estimation of the regime and calculation of the Power Flow. The result of optimization procedure consists of estimated values of measurement and total consumption of islands. These values are tested in the following sub-step:

5. Detection and elimination of bad measurements. If there is a measurement whose estimated value by far exceeds pre-defined thresholds of maximally allowed variation of estimated and measured values is called bad measurement and is eliminated from the further procedure of DSE. The sub-steps three and four are repeated until the moment when the values of mistakes of measured and estimated values for other remaining measurements smaller than the set thresholds. The remaining measurements represent a set of reliable measurements to which previously estimated values are allocated. On basis of those values calibration of consumption is done.

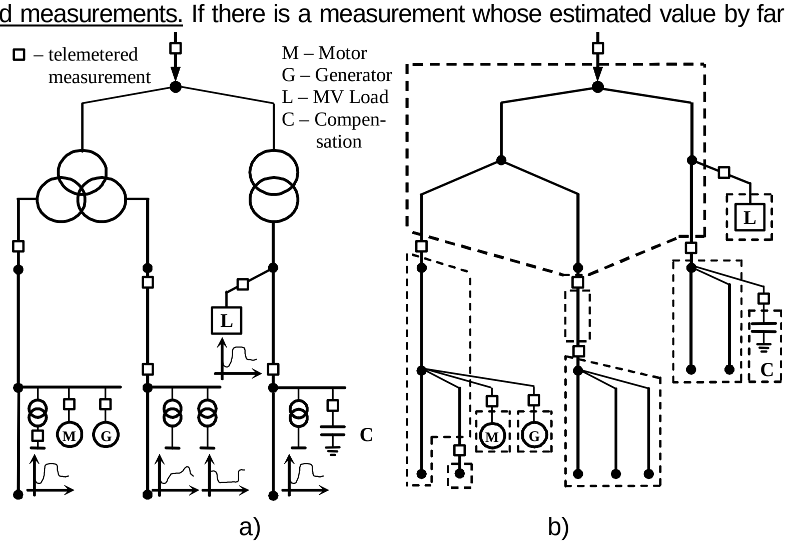

Figure 2 –The network (a) divided into nonobservable areas (b)

2.4. Calibration of consumption

If there are consumers with telemetered measurement values, their values are estimated in the previous step. Calibration (correction) of pre-estimated values of consumption of non-observable consumers (obtained in the first step DSE) is done on basis of estimated, telemetered values of measurement from the previous step. Calibration of load of the bus i, in the area n with N_n buses if:

$$x_{ni}^e = \frac{x_n^e}{x_n^p} x_{ni}^p , \qquad i = 1, \dots, N_n , \qquad n = 1, \dots, N_o . \quad (3)$$

2.5. Calculation of flow of power

On basis of values of module of phasor of voltage in the root DN and calibrated values of consumers' consumption in the form of active and reactive power, i.e. current magnitudes and power factors, enables calculation of flow of power and voltage state of the DN in question (11). The result of the calculation is the state of the network (phasors of voltage in all buses) brought to accord with estimated (verified) values of measurements.

3. VERIFICATION OF STATE ESTIMATION FUNCTION

Verification of presented mathematical model for DSE was carried out on the part of DN ED Sombor which is supplied with electrical energy by the transformer 110/20 kV/kV (Tr 1) in SS "Sombor 2". Tr 1 has power of 31,5 MVA and supplies DN in total length of 130 km in which there is 127 SS 20/0,4 kV/kV, with total installed power of 40,29 MVA. In the considered area, 8975 consumers are supplied with electrical energy (a part of area City of Sombor and villages Bezdan, Kolut, Bački Monoštor, Bački Breg and Kupusina). One-pole schema of the considered network part with display of measurement equipment is shown in Fig. 3.

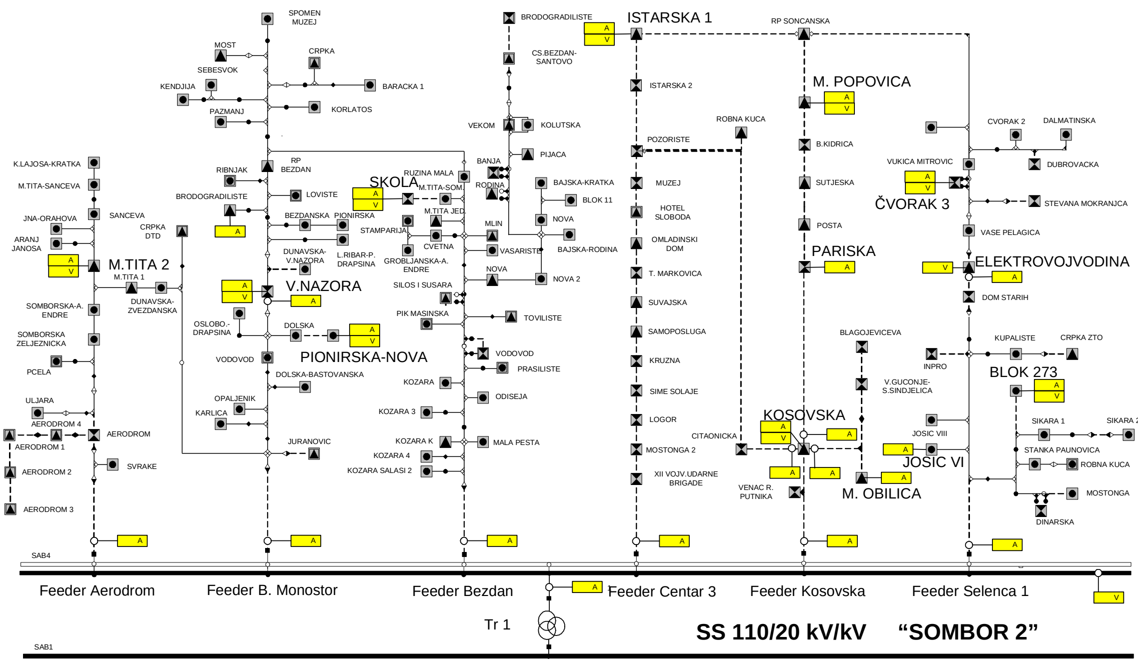

Figure 3 – display of measurement equipment

The experiment period of 64 days was divided into three characteristic periods: summer, autumn and winter. For the purpose of verification, the DSE function was done automatically, and its results were recorded each full hour. At the same time, in chosen SS 20/0,4 kV/kV on the voltage level 0,4 kV, fifteen-minute average values of measurement of current and voltage module were memorized. Quantification of state estimation results quality is based on comparison of estimated and simultaneously measured values of current and voltage modules, both in SS 110/20 and 20/0,4 kV/kV. For that purpose the quantitative indicators of variation between pre-estimated, measured, and estimated module values of current and voltage were used:

- average absolute and average percentage variation between measured and pre-estimated (α=*P*), and measured and estimated (α=*E*) values of current modules (*X*=*I*, these indicators are marked in the following text with *B* and *D* respectively) and the voltage (*X*=*V*, *F* and *G*, respectively) for *m* moment of measuring:

$$\Delta X_{sr}^{M\alpha} = \frac{1}{m}\sum_{j=1}^{m}\left|X_j^M - X_j^\alpha\right|, \qquad \Delta X_{sr\,\%}^{M\alpha} = \frac{100}{m}\sum_{j=1}^{m}\frac{\left|X_j^M - X_j^\alpha\right|}{X_j^\alpha}[\%], \qquad \alpha \in \{P,E\}; \tag{4}$$

- maximal absolute and maximal percentage variation between the measured and pre-estimated (α=P), and measured and estimated (α=*E*) values of current modules (*X*=*I*, *C* and *E*, respectively) and voltage (*X*=*V*, *H* and *I*, respectively) for m moment of measuring:

$$\Delta X_{\max}^{M\alpha} = \max\sum_{j=1}^{m}\left|X_j^M - X_j^\alpha\right|, \qquad \Delta X_{\max\%}^{M\alpha} = \max 100\sum_{j=1}^{m}\frac{\left|X_j^M - X_j^\alpha\right|}{X_j^\alpha}[\%], \qquad \alpha \in \{P,E\}. \tag{5}$$

Reliability of the quality of measured and historical data has been quantified by the ratio of values of their weight factors. For the examples that follow, if it was not specified, that ratio is T_{mer}:T_{ist}=100:30. In the figures the interrupted, dotted and full line present pre-estimated, measured and estimated values, respectively.

3.1 Verification of telemetered values of module measurements of 20 kV currents

For Tr 1 and six feeders, the table 1 shows values of quantitative indicators of error of estimation modules of 20 kV currents, for the tree considered periods (summer, autumn and winter) and for the whole experimental period (average). For each object the maximal period current *Imax* is marked.
On the basis of shown results it is obvious that despite of bad historical data (high values of medium and especially maximal variations between historical and measured values – indicators *B* and *C* reach values 30 and 60% respectively) and unjustified high trust in them T_{ist}=30, medium and maximal value of variation between estimated and measured values (indicators *D* and *E*) do not exceeds 10 and 20% respectively). It should be stressed that reduced trust in historical data, for example on T_{ist}=5, would give values of quantitative indicators *D* and *E* up to 3 and 10% respectively. Pay attention to the part 3.4.

Table 1 – Quantitative indicators of error of module estimation of 20 kV current

Object	Period	*Imax* [A]	*B* [A]	*B* [%]	*C* [A]	*C* [%]	*D* [A]	*D* [%]	*E* [A]	*E* [%]
Tr 1	summer	334,1	29.7	10.2	96.1	27.8	13.4	4.9	44.1	15.0
	autumn	484,7	24.6	6.9	103.9	27.2	9.5	2.8	42.5	13.0
	winter	560,0	63.7	17.9	167.5	48.0	19.2	4.6	73.2	15.7
	average	459,6	39.3	11.6	122.5	34.3	14.0	4.1	53.3	14.6
feeder Aerodrom	summer	34,1	3.0	12.2	9.1	42.8	1.0	4.1	4.2	16.5
	autumn	45,9	3.3	11.5	21.8	35.5	1.3	4.3	7.8	16.9
	winter	50,6	5.5	19.8	13.6	51.2	2.0	6.2	6.0	18.9
	average	43,5	3.9	14.5	14.8	43.2	1.4	4.9	6.0	16.8
feeder B.Monoštor	summer	55,3	6.9	22.0	19.5	59.3	3.1	8.5	8.2	18.3
	autumn	64,7	5.7	13.5	23.8	42.3	2.3	5.4	5.3	19.6
	winter	64,7	4.3	17.6	18.9	54.8	2.4	6.1	8.3	20.0
	average	61,5	5.6	17.7	20.7	52.1	2.6	7.6	7.3	20.3
feeder Bezdan	summer	83,5	4.7	7.6	17.1	33.2	1.7	2.7	6.7	9.4
	autumn	97,6	5.0	7.9	20.0	25.8	1.9	2.8	6.2	9.1
	winter	118,8	11.9	16.2	40.7	58.0	4.4	5.3	19.6	21.2
	average	100,0	7.2	10.6	25.9	39.0	2.6	3.6	10.8	13.2
feeder Kosovska	summer	71,8	15.6	29.1	25.0	49.0	5.3	10.5	8.0	20.7
	autumn	92,9	7.8	12.3	45.1	39.3	2.8	4.6	23.1	19.8
	winter	128,2	13.9	19.3	41.9	49.6	5.1	6.3	21.0	21.4
	average	97,6	12.4	19.5	37.3	46.0	4.4	7.2	17.3	21.3
feeder Centar III	summer	62,3	3.9	7.9	15.9	25.8	1.0	2.4	3.5	9.9
	autumn	95,3	6.0	8.4	31.2	28.8	2.1	3.1	10.4	9.9
	winter	130,6	20.3	26.5	39.9	57.1	7.7	8.5	15.0	15.8
	average	96,0	10.0	14.3	29.0	37.2	3.6	4.6	9.6	11.9
feeder Selenča 1	summer	71,8	4.8	9.5	14.7	29.8	1.3	2.9	5.4	14.2
	autumn	100,0	5.6	8.6	21.7	31.6	1.9	3.1	8.1	10.7
	winter	123,5	16.2	22.3	37.5	49.9	6.0	7.1	17.9	19.9
	average	98,4	8.9	13.5	24.6	37.1	3.1	4.4	10.5	14.9

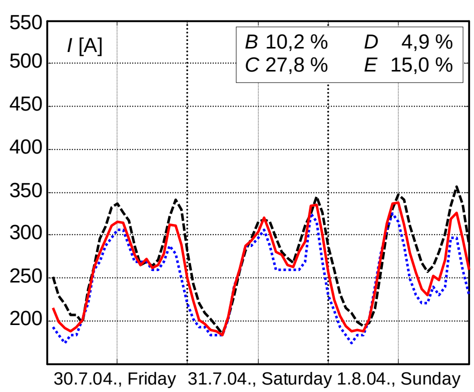

Figure 4 – 20 kV current Tr1 – summer

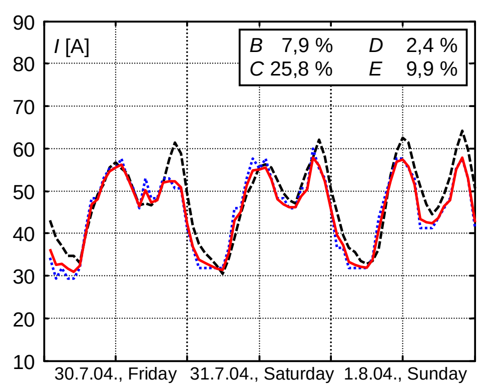

Figure 5 – 20 kV current feeder Centre III – summer

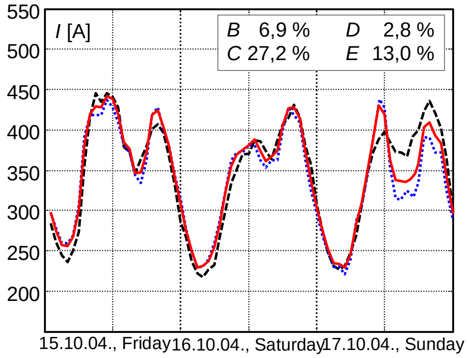

Figure 6 – 20 kV current Tr1 – autumn

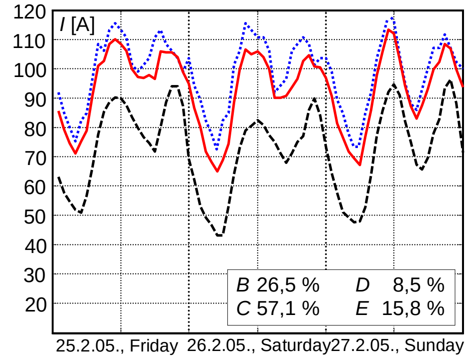

Figure 7 – 20 kV current Centre III - winter

DLP of pre-estimated, measured and estimated values of the module 20 kV currents, for Tr1 and feeder Centre III for three consecutive days (Friday, Saturday, Sunday) are shown on Fig. 4, 5, 6 and 7. The Fig. 4 and 5 refer to the summer period, Fig. 6 to the autumn period and the Fig. 7 to the winter period. On basis of shown results, noting the disballance between estimated and measured DLP, it is necessary to make correction of historical data on basis of which the estimation of 20 kV current Tr 1 for summer work day and Sunday and autumn Sunday, and the feeder Centre III for summer work day and Sunday and for all winter days were made.

3.2 Verification of 0,4 kV consumers' load estimation

Values of module quantifiers of 0,4 kV transformer currents in SS 20/0,4 kV/kV with measurements are shown in the table 2. Examples of DLP load estimation of two SS 20/0,4 /kV/kV of 250 and 400 kVA are shown in Fig. 8 and 9. Relatively high values of the quantitative indicator *D* (from 8,4 to 24,8) and especially the indicator *E* (from 34,3 to 45,4) are a consequence of high variations of load values and extremely bad historical data (the shape of DLP in the first place). Two specially bad examples SS M.Tito 2 with small and instable load for the summer period and SS M.Popovic with extremely high load in winter period are shown in the Fig. 8 and 9. A common problem is qualitative and quantitative estimation of their DLP. However, it is worth noticing that even in such difficult conditions, errors in state estimation (parameters *D* and *E*) are significantly smaller than the error values of load estimation (indicators *B* and *C*).

Table 2 – Results of verification of module estimation 0,4 kV currents.

Name SS 20/0,4 kV/kV	Sn [kVA]	Period	I_{max}/I_{nom}	I_{sr}/I_{nom}	*B* [A]	*B* [%]	*C* [A]	*C* [%]	*D* [A]	*D* [%]	*E* [A]	*E* [%]
SS M.Tita 2	250	summer	0,50	0,28	35,2	37,1	97,6	124,4	25,8	20,5	57,7	39,6
		autumn	0,72	0,33	52,0	28,2	128,5	64,6	50,1	22,8	75,0	42,1
SS Škola	400	summer	0,40	0,25	20,3	18,5	83,6	60,1	24,9	11,9	61,9	37,1
		autumn	0,49	0,30	31,8	14,4	134,3	42,8	30,2	14,5	133,0	47,0
SS Josić VI	250	summer	0,52	0,28	12,3	10,9	71,6	56,9	18,4	18,9	42,2	39,9
		autumn	0,66	0,38	35,7	19,9	92,1	45,4	31,4	18,0	77,1	41,2
SS Istarska 1	630	autumn	0,50	0,32	83,4	32,0	159,0	49,8	74,7	22,2	127,0	41,6
SS Kosovska	630	winter	0,52	0,34	70,5	23,5	214,5	61,8	49,9	14,2	153,4	38,0
SS Pariska	630	winter	0,86	0,40	131,4	31,5	273,8	68,4	96,3	21,1	171,1	42,5
SS M.Popovića	400	winter	1,14	0,75	120,0	26,4	255,3	69,7	67,2	13,7	135,2	43,2
SS M.Obilića	630	winter	0,63	0,41	80,6	24,6	190,2	63,2	49,2	13,4	161,9	45,4
SS Blok 273	250	winter	0,89	0,56	45,9	28,6	123,6	77,4	24,2	12,9	91,2	42,1
SS Čvorak 3	630	winter	0,62	0,39	72,1	21,7	253,7	79,0	32,5	8,4	128,0	34,3
SS V.Nazora	630	winter	0,62	0,38	78,9	21,7	211,0	59,2	48,3	12,8	136,7	38,2
SS Pionirska	250	winter	0,59	0,36	23,9	21,3	59,8	53,2	16,9	14,3	40,2	37,8

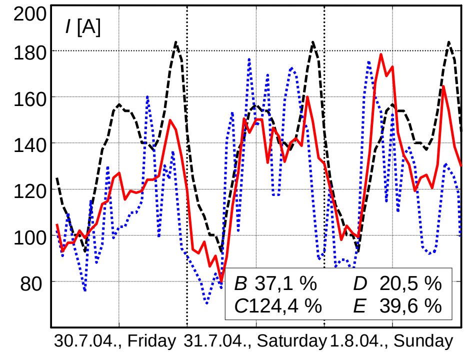

Figure 8 – 0,4 kV current SS M.Tita 2 – summer

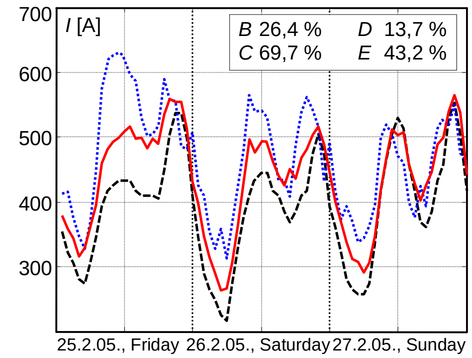

Figure 9 – 0,4 kV current SS M.Popovića – winter

3.3 Verification of estimated values of voltage module

The table 3 shows values of quantitative indicators of variation between pre-estimated, measured and estimated value of voltage module on 20 kV busbar Tr 1 and 10 voltage modules on 0,4 kV busbars in SS 20/0,4 kV/kV. On basis of shown results it can be noticed that in spite of high medium and especially maximum variations between historical and measured data – indicators *F* and *G*, estimation shows that medium and maximal values of variation between estimated and measured values (indicators *H* and *I*) do not exceed 1,20 and 2,84% respectively. DLP of pre-estimated, measured and estimated 20 kV voltage module values for Tr 1 and 0,4 kV voltage for SS "Pionirska", for three consecutive days (Friday, Saturday and Sunday) are shown in Fig. 10 and 11.

Table 3 – Verification results of estimation of 20 kV and 0,4 kV voltage modules

Name Energetic object	Period	*F*		*G*		*H*		*I*	
		[V]	[%]	[V]	[%]	[V]	[%]	[V]	[%]
Tr 1	summer	156,25	0,89	423,00	2,03	102,83	0.49	336,00	1.61
	autumn	118,99	0,95	460,00	2,12	118,99	0,56	361,00	1,72
	winter	250,36	1,19	490,00	2,25	140,87	0,62	402,00	1,99
SS M. Tita 2	summer	3,63	0,88	12,00	2,97	2,52	0,61	9,01	2,17
SS Škola	summer	5,11	1,21	14,52	3,55	4,23	1,03	11,66	2,84
	autumn	2,79	0,67	9,18	2,16	2,92	0,71	8,25	1,94
SS Istarska 1	autumn	4,93	1,21	12,99	3,29	3,54	0,87	11,02	2,27
SS Kosovska	winter	5,59	1,42	14,38	3,74	4,92	1,20	9,33	2,41
SS M. Popovića	winter	4,79	1,22	15,04	3,88	4,35	1,07	9,83	2,53
SS Blok 273	winter	4,37	1,08	17,83	4,32	3,98	0,98	10,46	2,57
SS Čvorak 3	winter	4,58	1,17	13,91	3,61	3,95	0,97	10,66	2,62
SS Elektrovojvodina	winter	3,58	0,93	13,41	3,54	3,05	0,76	10,77	2,84
SS V. Nazora	winter	2,81	0,72	11,10	2,93	2,85	0,70	11,06	2,69
SS Pionirska	winter	3,37	0,85	15,27	3,92	3,13	0,79	8,92	2,03

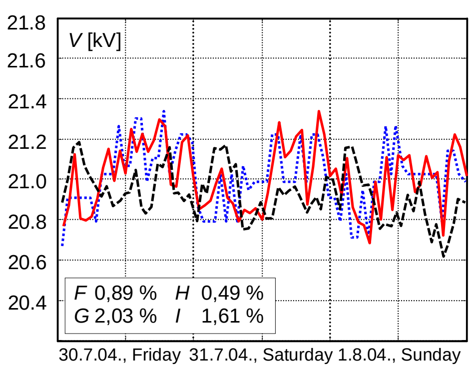

Figure 10 – 20 kV voltage TR 1 – summer

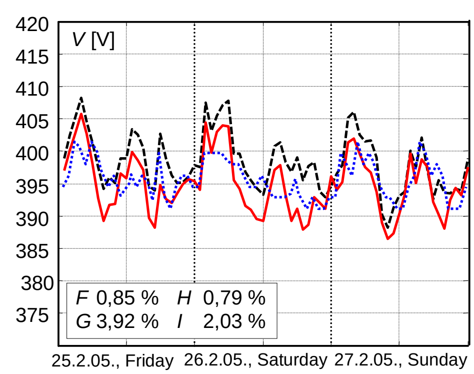

Figure 11 – 0,4 kV voltage SS Pionirska – winter

3.4 Influence of weight history factor

The table 5 shows the values of quantitative indicators of variation of pre-estimated, measured and estimated values of transformer currents in SS 20/0,4 kV/kV. The values present work day Friday 25. 02. 2006. for the constant values of trust in telemetered data T_{mer}=100 and five values of weight history factor T_{ist} = 30, 20, 10, 5 and 1. Influence of ratio of weight factor values of trust in historical and telemetered data on the quality of estimation DLP module 20 kV current Tr 1 and 0,4 kV transformer current in SS Kosovska and SS Čvorak is shown in Fig. 12, 13 and 14 respectively. Influence on estimation quality of DLP module of 0,4 kV voltage in SS V.Nazor is shown in Fig. 15. On the basis of the results it can be noticed that for the majority of examples, by decrease of trust in historical data, the quality of results DSE is raised (that is consequence of an already noticed problem – extremely bad historical data). It should be stressed that this is not a general rule; for example quantitative indicator E for SS Čvorak and SS Pionirska reaches the smallest value for T_{ist} = 30 and T_{ist} = 5.

Table 5 – Quantitative indicators of variation 0,4 kV currents for SS 20/0,4 kV/kV

SS 20/0,4 kV/kV Mesto Izvod	T_{ist}	*B*		*C*		*D*		*E*	
	%	[A]	[%]	[A]	[%]	[A]	[%]	[A]	[%]
SS Kosovska Sombor ″Kosovska″	30	64,9	22,5	138,9	49,3	33,7	10,1	89,4	27,0
	20					30,9	9,1	83,9	24,9
	10					27,5	8,1	77,0	22,4
	5					25,8	7,6	72,9	21,0
	1					24,5	7,2	69,2	19,7
SS M. Popovića Sombor Kosovska	30	114,9	30,2	254,3	63,6	63,0	14,0	190,8	41,2
	20					57,8	12,7	183,3	38,9
	10					52,8	11,4	173,9	36,2
	5					50,5	10,8	168,1	34,6
	1					49,3	10,4	162,9	33,1
SS M. Obilića Sombor Kosovska	30	68,4	21,7	158,0	51,5	35,6	9,6	98,0	30,9
	20					36,1	9,5	96,1	30,1
	10					37,1	9,4	93,8	29,2
	5					37,8	9,4	92,6	28,7
	1					39,0	9,5	91,6	28,3
SS Blok 273 Sombor Selenča 1	30	39,0	24,6	79,1	46,1	20,5	10,8	42,9	24,9
	20					18,9	9,8	41,0	23,3
	10					17,0	8,6	38,6	21,3
	5					16,5	8,2	37,2	20,1
	1					17,0	8,4	37,6	19,1
SS Čvorak 3 Sombor Selenča 1	30	52,5	15,4	154,7	45,1	25,2	6,3	62,4	14,6
	20					25,9	6,5	50,6	13,5
	10					27,5	6,8	57,0	13,7
	5					28,7	7,1	60,8	15,0
	1					31,3	7,6	64,2	16,2
SS V. Nazora B Monoštor B Monoštor	30	78,9	21,0	211,0	59,1	47,8	12,0	99,2	25,1
	20					45,4	11,4	93,9	25,6
	10					42,7	10,8	87,1	26,1
	5					41,9	10,6	90,4	26,4
	1					48,1	10,7	93,8	26,7
SS Pionirska B Monoštor B Monoštor	30	23,4	20,5	59,1	51,3	16,5	13,8	37,9	34,2
	20					15,8	13,1	36,5	33,2
	10					14,9	12,4	35,6	32,2
	5					14,7	12,2	35,5	32,5
	1					16,6	13,9	37,8	34,8

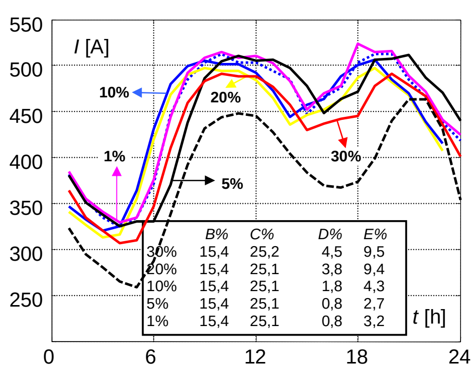

Figure 12 – 20 kV current Tr 1 – winter

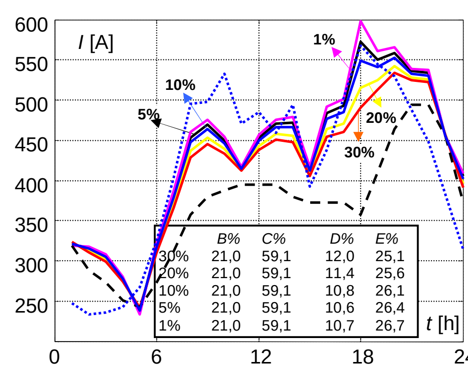

Figure 13 – 0,4 kV current SS V. Nazor – winter

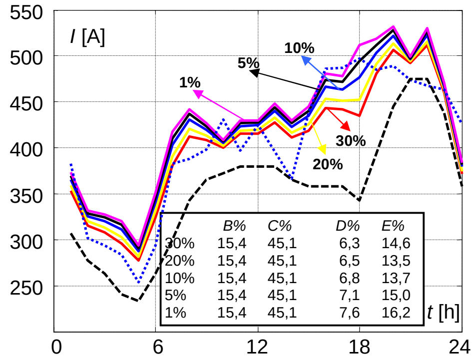

Figure 14 – 0,4 kV current SS Čvorak – winter

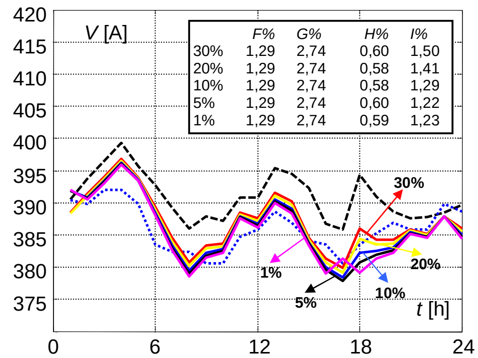

Figure 15 – 0,4 kV voltage SS V.Nazor – winter

4. CONCLUSION

The DSE function is the basic and most important analytical function for DN calculation. It is used for estimation and analysis of (previous, present and future) state of DN. This paper gives a brief description of the idea of the simple, fast and robust Real-Time Distribution State Estimator. Its speed is a result of reduction of all parts of the network in the first place (in the mathematical network model) that are not remotely observed. Its strength is evident in the fact that it can be adapted to any distributive network - from those for which only historical data are available to those which are totally remotely observed. The main aspect of this paper is its efficiency verification in the field. The presented results are only a small but representative part of the results obtained by comparing values of long, complex measurements and application of DSE in real time, carried out in a couple of recent years. The paper emphasizes the main conclusions: 1 – The importance of historical and telemetered data is not only stressed, but their relative weight has practically been stated (DSE has been projected in the way that its efficiency is in direct proportion with the size of observed part of the network and quality of historical data); 2 – the quality of DSE results rises with the rise of number of consumers supplied by the element whose size is estimated; 3 – Voltage estimation gives very good results, which enables carrying out centralized voltage control. Finally, the paper proves that the real time DSE is not only possible but is also sufficiently reliable and accurate for both distribution network regime analysis in on-line mode and its management in real time.

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Key words: distribution network, load calibration, power flow calculation, state estimation