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Model of Digital and Signal Channel in the Network of Serbian Electric Power Industry

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Abstract: In this paper we use data from extensive measurements, which are implemented in telecommunication networks of electric power industries in the six countries. The model of digital telecommunication channel and the model of hypothetical signaling CCS No7 channel under the influence of bursty errors are presented in the paper. These models can express very accurately data and signaling transmission in the digital telecommunication network (TN) of the Serbian Electric Power Industry (SEPI). We consider the model of digital and signaling channel first and after that analyse the availability of these channels under the influence of bursty errors.

Keywords: Digital telecommunications channel, signaling CCS No7 channels, telecommunication network, Serbian Electric Power Industry, bursty errors.

1 Introduction

THE development of digital techniques has inevitably influenced the electric power telecommunication network. This network was analog, and the procedures for the reduction (but not for elimination) of the impact of electric power networks on the telecommunication networks were used. The problem of a significant impact of electric power networks on the telecommunication network remains, despite the application of digital techniques. In this paper we want to estimate the transmission capabilities of information and signaling digital 64 kb/s CCS No7 channels in the telecommunication network of the SEPI, [1].

In [2], which contains a list of 97 references, the results of the great number of disturbance measurements and observations in telecommunication networks of electric power industries in Japan, Italy, Switzerland, Spain, the former Soviet Union and former Yugoslavia, are presented.

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2 Gilbert-Elliott Channel Model

In order to determine the availability of digital and signaling CCS No7 channel under the influence of bursty errors, using the Gilbert model [3], we consider the so-called advanced Gilbert-Elliott model. Fig. 1.a) presents the Gilbert-Elliott's model, and figure Fig. 1.b) presents the possible distribution of bursty errors in function of time. In this model, there is a state of low error probability of incorrectly transmitted bits, which is marked as G (Good), and the state of higher probability of incorrectly transmitted bits, which is marked as *B* (Bad), Fig. 1.a).

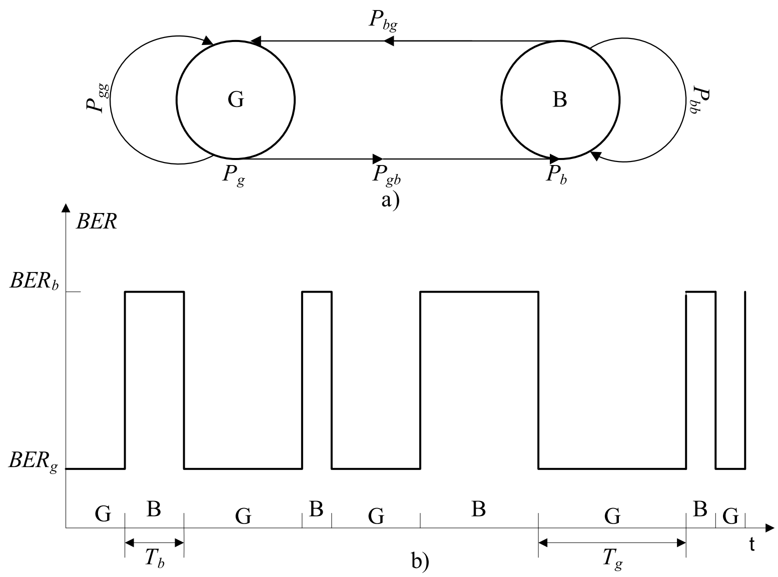

Fig. 1. a) Gilbert-Elliott model; b) The distribution of bursty errors in the function of time

The bit error rate (BER) in a state of low probability of incorrectly transmitted bits, *G*, is marked with BERg, and the bit error rate in a state of higher probability of incorrectly transmitted bits, *B*, is marked with BERb, Fig. 1.b). The probability that the channel is found in the state *G* is P_g, and the probability that the channel is found in the state *B* is P_b. From this it follows that holds $P_g + P_b = 1$. Channel transition probability from state *G* to state *B* is P_{gb}, and from state *B* to state *G* is P_{bg}. The probability that the channel is found in the state *G* can be calculated as follows (Fig. 1.a)):

$$P_g = \frac{P_{bg}}{P_{gb} + P_{bg}}$$

Analogous to the above expression, the probability that the channel is found in state

B, is calculated using the following expression:

$$P_b = \frac{P_{gb}}{P_{gb} + P_{bg}}$$

The time duration of the channel state G is the random variable T_g with the mean value t_g. T_b and t_b mark the time duration of state B and its mean value. Quotient of the probability that the channel is in state G and state B is equal to the ratio of mean time spent in states G and B, $P_g/P_b = t_g/t_b$.

3 Model of Digital Channels in the Network of Serbian Electric Power Industry

Digital telecommunication channels in network of SEPI differ from similar channels in the public network in the fact that power network greatly affects the operation of telecommunication network (TN) of Electric Power Industry (EPI). This influence can be summarized in the following:

- a number of connections are made across transmission lines;
- in the energy facilities are located, in most cases, and telecommunications nodes.

It is therefore necessary to first determine the type of disturbances in electricity telecommunications node. To determine the types of disturbances in electricity telecommunications node will be used [2]. The essential conclusions stated in [2] are as follows:

1. Switching in the power network is the main source of interference in the EPI telecommunication network.
2. Errors in the power network node occur almost exclusively as bursty, and this is a consequence of switching in the energy system. (The time duration of a very high error rate, as was previously mentioned, will be marked by T_b, and the time duration of very low error rate between high error rate periods is indicated by T_g. Time intervals T_b and T_g are measured and determined by the cumulative distribution function, which is graphically represented in Fig. 2 and Fig. 3. Fig. 2 presents the cumulative distribution of the time interval of high error rate in the node of TN SEPI, the worst case, [2], while Fig. 3 presents the cumulative distribution of the time interval of low error rate in the node of TN SEPI, the worst case, [2]. With t_b will be mark the mean duration of very high level of errors, T_b, where $t_b = 740$ms, and the mean duration of a period of very low-level errors, T_g, will be marked with t_g, where $t_g = 9.23$ hours).

3. The measured intensity of bit errors (for speed 600 bit/s and 1200 bit/s) in the interval bursty errors is BERb and has very high values that are moving in the range of 0.05 to 0.4. The measured intensity of bit errors in the intervals between the bursty errors, BERg, has a very small value of $1 \times 10^{-8} < BERg < 1 \times 10^{-7}$.

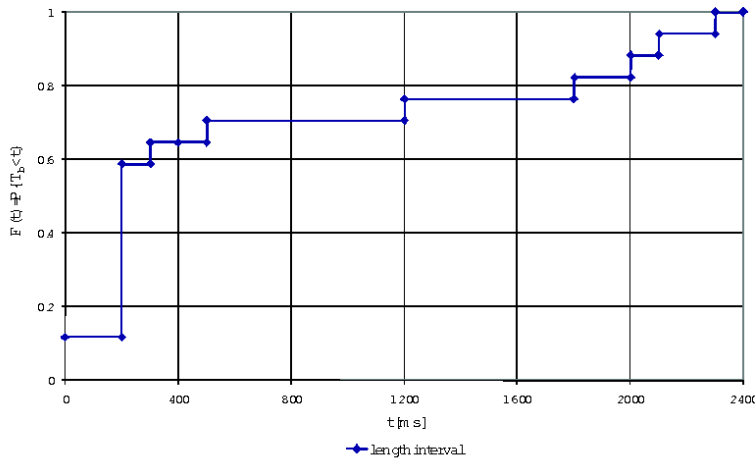

Fig. 2. Cumulative distribution of the time interval of high error rate in the node of TN SEPI, the worst case, [2]

Based on these measurements the conclusion under the number 3, adopt two assumptions are very reasonable, as follows:

- Disturbance in the telecommunications node affect all devices (exchange, terminals, measuring equipment) regardless of the fact that a connection generated by radio, and a fiber optic connection.
- The BER in the interval Tb retains its very high value regardless of the size of bit's flow.

If we rely on mentioned conclusions, and take into account these two assumptions, the telecommunication node in electric power network may be observed as a node with channels presented by Gilbert-Elliott channel model with two error rates, [4], [3]. Gilbert-Elliott channel model is referred to in this paper (Section 1).

Criteria defined in ITU-T Recommendation G.821, Annex A, [5] can be used for the assessment of the availability of digital 64 kb/s channels. The availability of digital 64 kb/s channels under the influence of bursty errors is analyzed in [1], [6]. From [6] can be seen that the effect of bursty errors is negligible if $t_b < 10s$ and $t_g \gg t_b$.

The availability of this channel is practically equal to the availability of channels where the BER is equal to BERg. It is a very high value because the availability of digital 64 kb/s channel is growing rapidly $(A > 1 - 1 \times 10^{-10})$ when $BERg < 8 \times 10^{-4}$. Based on the measurement results from [2], time intervals Tb are determined using cumulative distribution function and presented graphically in Fig. 2. It can be seen from Fig. 2 that the $T_b \leq 2.4$s and $t_b = 0.74$s, so the availability of digital 64 kb/s channel is always close to a value of 1.

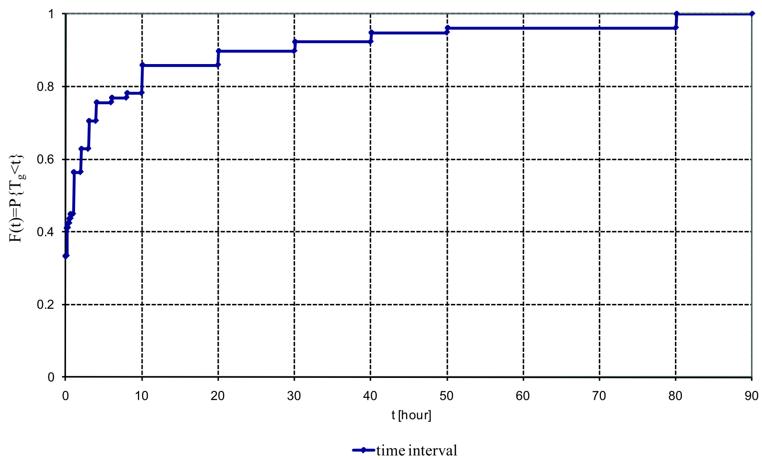

Fig. 3. Cumulative distribution of the time interval of low error in the node of TN SEPI, the worst case, [2].

Based on the measured values of interference in a number of measurements in several countries, [2], it can be concluded that interference will not significantly affect the availability of digital 64 kb/s channels, as intervals of bursty interference are always shorter than the critical interval of 10s, [6], [1].

4 Model of the Signaling Channels in the Network of SEPI

As is well known and referred in [1], the availability of CCS No7 signaling channels depends on the bit error rate. Availability is calculated using the mean time of normal operation, E(X), and mean synchronization time, E(Y), [7], for the measured values of BER. Using the measurement results from [2], it is obvious that telecommunication channel in the network SEPI in the interval Tb has a very high bit error rate $(0.05 < BERb < 0.4)$, so that practically every signal unit is wrong.

The function of monitoring the frequency of incorrectly transmitted signal units per CCS No7 channel, in a state of normal operation, use of SUER monitor, (Signal Unit Error Rate). SUERM algorithm, [1], which monitors the signaling CCS No7 channel in a state of normal operation, functions on the principle of leaky bucket. It is enough, according to this algorithm, that 64 consecutive faulty signal units appear, and the state of normal operation will be ended.

The probability that the interruption of normal operation is caused during an interval of bursty errors will be marked with the P_{co}. This probability depends on the length of signal units. First, we observe an unoccupied signaling channel. In this state Fill-In Signal Units (FISU) are transmitted on the signaling channel. FISUs are composed of 6 octets $(6 \times 8 = 48$ bits). The time required to transfer 64 FISUs is 48ms. If we now observe the signaling channel during high error rate, BERb, while long signal units of 150 octets $(150 \times 8 = 1200$ bits) are transmitted, then the time requred to transmit them is 1200ms.

The probability of P_{co} will be calculated using data from the Fig. 2., for the duration of two very high level of error T_b, and $T_b > 48$ms and $T_b > 1200$ms. It is obvious that the $P_{co1} = P(T_b > 48\text{ms}) \approx 0.97$ and $P_{co} = P(T_b > 1200\text{ms}) \approx 0.24$. Mean time to interruption of normal operation can be calculated as the mean time until the first success of the series Bernoulli testing, each bursty error one experiment, which applies geometric distribution [1]. Mean time to interruption of normal operation, $E(X)$, is given by expression:

$$E(X) = \frac{t_g}{P_{co}}$$

$$1.031t_g < E(X) < 4.17t_g$$

From this double inequality, it can be concluded that the mean time of the correct operation of the signaling CCS No7 channel (depending on the length of the signaling messages) is in the range between one and four intermediate interval t_g ($t_g = 9.23$h, Fig. 3.) with low error rate, BERg.

In calculating the mean synchronization time, $E(Y)$, of the signaling CCS No7 channels, two cases are analyzed, the process of normal synchronization and the process of rapid synchronization, [1].

The testing period of time that represents the time required to receive (1×10^{16}) groups of 8 bits, and that in this time interval is not found more than 3 wrong bits, in the normal synchronization procedure, takes about 8.2s. Synchronization and recovery of the signaling channels are carried by the controlled test periods of time. If the signaling channel is under the influence of low error rate, the synchronization of the channel is almost always performed after the first test period. This means that the mean recovery time or malfunction of signaling channel, $E(Y)$, is about 8.2s, $(E(Y) \approx 8.2s)$, measured from the end of the interval of bursty errors, ie. of channel outage from normal operation. As the mean time of normal operation, $E(X)$, and mean time synchronization, E(Y), are calculated, one can calculate also the availability, A, of the signaling CCS No7 channel in the case of the normal synchronization, and it is:

$$A = \frac{E(X)}{E(X) + E(Y)}$$
$$0.99976 \leq A \leq 0.999941$$

The process of rapid synchronization takes 0.5 s. This is a test period of time that represents the time required to receive (1×10^{12}) groups of 8 bits, and that in this time interval is not found any wrong bit. So, the mean time to recovery or fault signaling channel, E(Y), is 0.5s, $(E(Y) \approx 0.5s)$. The availability of CCS No7 signaling channels in the case of rapid synchronization is given by:

$$A = \frac{E(X)}{E(X) + E(Y)}$$
$$0.999985 \leq A \leq 0.999996$$

In electric power telecommunication network we must consider time intervals with very high intensity of interference caused by power network, affecting the operation of the CCS No7 signaling channels. The availability of CCS No7 signaling channels depends on these disturbances, but not excessively, ie. interference does not cause the availability drop below 0.99976. The main reason for the relatively small impact of noise on the signaling channel is a relatively high value of time between the bursty errors ($t_g = 9.23$h, Fig. 3.). Since the availability depends on the length of the signal unit, it follows that the availability is the least for unoccupied channel, ie. disturbances have the greatest impact on the availability of unoccupied channels, while the increase in signaling traffic and in the length of signal units increases the availability of the signaling channel.

5 Conclusion

On the basis of the adopted models of digital channels with bursty errors in the telecommunication network of SEPI, we can calculate the expected availability of the information channel with signal flow 64kb/s and signaling CCS No7 channels in TN SEPI. In accordance with the conclusions of paragraph 3, the availability of information channels with the flow 64kb/s in TN SEPI is anticipated to be close to ideal values of availability, i.e. unit. According to the model, the probability of bursty errors longer than 10s is negligible and so bursty errors has negligible impact on the availability.

The availability of CCS No7 signaling channels in the network of SEPI would, however, suffer from bursty errors. The duration of group (bursty) errors in the adopted model is comparable with the time response of SUER monitor, so the signaling channel can be removed from normal operation during the bursty error. Thus, the availability of digital signaling channels, which operate in the TN of SEPI, would be less than ideal. Fortunately, a very long time intervals between the bursty errors do not allow a decrease in availability. As is well known that the value of the availability of CCS No7 channels depends on the type and duration of signaling messages, in paragraph 4 was calculated that the availability is between 0.99976 and 0.999941, which is still acceptable value.

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