Determining the operating performance through electrical measurements of a hydro generator

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Abstract. This paper presents the results obtained by experimental measurements regarding the determining of the operating performance of a Hydro generator, through electrical measurements before the refurbishment of hydro aggregates. Experimental measurements were taken to determine the characteristic by putting off load and also by putting on load regimes for power between 1 and 5 MW of hydro generator. These electrical measurements are to establish appropriate measures in terms of constructive and functional in order to bring the nominal parameters of that hydro aggregate.

1. Introduction

In terms of operation efficiency, the technical and economic parameters for hydraulic machines operating in all industrial fields [1], a special attention should be given in the phase of design and technological development.

In the case of hydropower, which operates in a hydro power plant, a key factor is to maintain the temporal parameters that define the quality materials used in manufacturing [2] a defined by the number and duration of maintenance interventions respectively for their lifetime.

For example, the normal functioning of the hydraulic hydro turbines is influenced greatly in terms of vibration [3].
In this way, it can still be registered through various experimental measurements of hydropower through experimental laboratory research also through numerical simulations, the following:

- Testing and performance evaluation tests index, partial downloads and so on [4]. These measurements were made on a total of 18 small hydroelectric power plants;
- Monitoring the hydro aggregate parameters during operation is normal and transient [5]. Also, after dynamic balancing, certain parameters (voltage, rotation and vibration) were directly measured [6] or by indirect methods [7] and thermodynamic methods [8], where they recorded satisfactory measurements.

At smaller scales, the pumps, turbines, generators [9] and the phenomenon of partial discharge [10] or laboratory simulation respectively, were achieved with great interest [11-13];
- Research on cavitation respectively cavitation erosion, which is mainstay and acting destructively on materials used to manufacture hydraulic turbine rotors [14-16].

In conclusion, because of these features, the operation parameters inside of hydraulic turbines and hydro power plants respectively is influenced to a large extent and in time due to the number of hours of operation, imposed by overhauling the hydropower rehabilitation.

In this sense, this paper highlights several results obtained by measurement experiments on a high hydro power from a hydro power plant in Romania, in the feature idling and feature under load at different powers respectively partial discharge levels.

These results through tables and diagrams characteristic highlight the important parameters of hydro development. All measurements in this paper were made in accordance with applicable standards [17], [18].

2. Experimental measurement before dismantling the generator

To measure active power, tensions or currents respectively across generator electrical parameters analyzer was used and type VPA323 process parameters, a laptop for data processing, as in Figure 1. The hydro speed was measured with a laser speed sensor, such QS30LDQ.

![Analyzer of the parameters of the VPA323 type](image)

2.1. Measurement electrical parameters steady idle excited and transient arousal

Before removing the rehabilitation of hydro, it is very important to assess the actual operating performance in electrical and mechanical terms. In this regard, certain electrical parameters were measured vibrations respectively (Figure 1).

The electrical parameter values are given in Table 1.
Table 1. Values of the electric parameters in a stable idle functioning environment as well as in a transitory excited mode

| Time [s] | Revolution [RPM] | Stable idle functioning mode | Transitory excited mode R |
|---------|------------------|-----------------------------|---------------------------|
|         |                  | $U_{\text{line}}$ [V] | $U_{\text{exG}}$ [V] | $I_{\text{exEx}}$ [A] | $U_{\text{line}}$ [V] | $U_{\text{exG}}$ [V] | $I_{\text{exEx}}$ [A] | $I_{\text{exEx}}$ [V] |
| 1       | 167.2            | 6139.82                    | 84.39                    | 21.625                   | 6.82                   | 168.3                  | 2.33                   | 1.839                   | 0.26                   |
| 2       | 167.2            | 6141.66                    | 84.39                    | 21.67                    | 6.83                   | 256.08                 | 9.62                   | 8.66                    | 0.68                   |
| 3       | 167.2            | 6143.4                     | 84.45                    | 21.632                   | 6.83                   | 825.49                 | 44.61                  | 25.079                  | 2.49                   |
| 4       | 167.2            | 6144.93                    | 84.49                    | 21.7                     | 6.83                   | 2360.26                | 86.84                  | 23.709                  | 4.93                   |
| 5       | 167.19           | 6146.21                    | 84.45                    | 21.712                   | 6.83                   | 3784.43                | 92.55                  | 18.024                  | 5.78                   |
| 6       | 167.19           | 6147.61                    | 84.5                     | 21.646                   | 6.84                   | 4807.77                | 87.04                  | 17.531                  | 6.03                   |
| 7       | 167.19           | 6149.24                    | 84.56                    | 21.753                   | 6.84                   | 5351.76                | 81.94                  | 18.323                  | 6.12                   |
| 8       | 167.2            | 6150.82                    | 84.58                    | 21.665                   | 6.84                   | 5591.79                | 79.4                   | 18.744                  | 6.18                   |
| 9       | 167.21           | 6152.07                    | 84.59                    | 21.63                    | 6.85                   | 5699.34                | 77.65                  | 19.03                   | 6.17                   |
| 10      | 167.21           | 6153.21                    | 84.62                    | 21.682                   | 6.85                   | 5743.92                | 76.68                  | 19.428                  | 6.16                   |
| V.      | 167.20           | 6147.60                    | 84.52                    | 21.69                    | 6.84                   | 3458.91                | 63.86                  | 17.036                  | 4.48                   |

Electrical parameters steady idling respective excited arousal phase are: line voltage generator $U_{\text{line}}$; phase voltage $U_{\text{phaz}}$; $U_{\text{exG}}$ excitation voltage generator; $U_{\text{exEx}}$ excitation voltage excitation and the excitation current exciter $I_{\text{exEx}}$.

Figures 2 and 3 show the change in regime starting measured parameters and idle respectively excited stabilized waveform regime stabilized idle excited.

![Figure 2. Measurement scheme for idle functioning](image)

![Figure 3. Measurement scheme for idle functioning mode](image)
2.2. Characteristics of empty functioning

Feature idling is given by $U_0 = f(I_{exEx})$ for $n = ct. (F = ct)$ and $I = 0$, where $U_0$ is the voltage across the generator under idling [19], [20]. Whereas under idle load current is zero ($I = 0$), the voltage across the generator will be equal to the electromotive voltage $U_{eE}$, flow-induced excitation current $\Phi_p$ determined $I_{exEx}$ the winding rotor. The phasor diagram (Figure 4), the electromotive voltage $U_{eE}$ is out of phase $\pi / 2$ after the flow of excitation respectively after excitation current, and Figure 5 is presented under the scheme as idle.

![Figure 4. Phased diagram of the synchronous generator in idle functioning](image)

![Figure 5. Measurement scheme in idle functioning mode](image)

In conditions where the generator rotation is maintained constant ($n = 167.2$ rpm) which corresponds to the frequency $f = 50$ Hz, changes the excitation current of the excitation winding and $I_{exEx}$ the corresponding values of the voltage read at the terminals $U_0$.

The graphical representation of the variation $U_0 = f(I_{exEx})$ is shown in Figure 6 and Figure 7 extrapolation.

![Figure 6. Idle functioning characteristic](image)
Figure 7. Idle functioning characteristic (extrapolated)

Of characteristics resulting idle following: excitation current gap: \( I_{exEx0} = 6.2 \, A \); excitation current idle: \( I_{exEx0} = 7.2 \, A \); maximum excitation current \( U_0 = 1.2 \cdot U_n = 7560 \, V \), resulting in extended idling feature: \( I_{exExm} = 10.7 \, A \).

The state of saturation of the magnetic circuit can be appreciated from the report:

\[
\frac{I_{exExm}}{I_{exEx0}} = \frac{10.7}{7.2} = 1.48
\]

where:

- \( I_{exEx0} \) is the current excitation voltages corresponding to an idle \( U_0 = A \),
- \( I_{exExm} \) excitation current voltages corresponding to an idle \( U_0 = 1.2 \cdot U_n \).

2.3. Characteristic of charged functioning (in V)

The characteristic \( V, I = f(I_{exEx}) \) for \( U = ct., P = ct., \) corresponds to the phase diagram [19] in Figure 8. The condition of \( P = ct. \), requires the active component of current flowing \( I_A = ct. \) and place the tip of the variation of \( I_{exEx} (U_{ct}) \) is right (\( \Delta \)). In the diagram, the machine is overexcited and debit inductive power network.

If you start to lower excitation current, the current drops to the minimum value when the generator is running toward the basket network \( \cos \phi \approx 1 \); decreasing further excitation (under exciting the engine), the current rise again and \( \cos \phi \) is capacitive.

For a given power \( P \), it is necessary that excitement does not fall below a certain minimum. In Figure 5, was represented by a dotted line and the minimum value in the synchronous operation \( U_{elmin} \) is possible power not considered. The curve \( I = f(I_{exEx}) \) is obtained; it is in the form of a V.

For another power value \( P = ct. \) higher right (\( \Delta \)) moves so as to increase the value of \( I_n \). Excitation current value necessary to establish new, take is also higher toe and \( V \)-axis system \( (I_{exEx}, I) \) moving up and to the right.
In Figure 9 are the characteristics $I = f(I_{\text{exEx}})$ for different powers [21]. The curve represented by open, connecting the tips of the V curves separates from the viewpoint of reactive load, the operation of the generator inductive, capacitive generator of the (receiver inductive).

![Figure 8](image1.png)  
**Figure 8.** The phased diagram of a synchronous generator functioning at $U=ct.$, $f=ct.$, $P=ct.$

![Figure 9](image2.png)  
**Figure 9.** The V curves of a synchronous engine for different values $P=ct.$.

The curve represented capacitive discontinued operation area indicates the limits to which may be deducted for various excitation power $P = ct.$, such as synchronous operation is possible.

Measurement scheme load operating mode is shown in Figure 10.

![Figure 10](image3.png)  
**Figure 10.** The measurement scheme for the charged functioning system

For different values of active power, load characteristics corresponding amounts that power. For different values of the excitation current, the corresponding values are read stator current, stator voltage, active and reactive powers.

These results are presented below in tables and graphs for power between $1 \div 5 \text{ MW}$. For these 5 attempts, the generator is connected on the network, measuring the corresponding values: line voltages $U_{RS}$, $U_{ST}$, $U_{RT}$; stator current $I$; $I_{\text{exEx}}$ excitation current; $U_{\text{extG}}$ excitation voltage generator; $U_{\text{extEx}}$ exciter excitation voltage; active power; reactive power $\cos \phi$ power factor respectively frequency $f$. 
Tables 2 – 6 shows the values of the electrical parameters regime under load for power values from 1 through 5 MW cut-in feature that these powers (Figures 11 – 15).

### Table 2. The values of the electric parameters in charged functioning mode for P=1 MW

| Time | Values of the electric parameters |
|------|-----------------------------------|
| t    | f [Hz] | P [MW] | Q [Mvar] | cos φ | U<sub>line</sub> [V] | I [A] | U<sub>exG</sub> [V] | U<sub>exEx</sub> [V] | I<sub>exEx</sub> [A] |
| [s]  |       |       |         |       |        |       |       |        |         |
| 1    | 50  | 1.68 | 0.63  | 0.93  | 6164.26 | 111.15 | 89.13 | 24.096 | 7.5     |
| 2    | 50.03 | 1.59 | 1.83  | 0.66  | 6216.14 | 148.39 | 105.03 | 28.119 | 8.96    |
| 3    | 50.02 | 1.68 | 1.98  | 0.65  | 6221.32 | 153.2 | 107.58 | 28.864 | 9.02    |
| 4    | 50.02 | 1.65 | 2.4  | 0.57  | 6249.98 | 175.21 | 113.79 | 30.901 | 9.79    |
| 5    | 50.02 | 1.59 | 3.75  | 0.39  | 6314.61 | 244.51 | 133.84 | 37.207 | 11.97   |
| 6    | 50.01 | 1.59 | 3.9  | 0.38  | 6316.75 | 253.05 | 136.77 | 38.746 | 12.3    |
| 7    | 50  | 1.56 | 4.02  | 0.36  | 6323.87 | 259.94 | 138.38 | 38.966 | 12.51   |

![Figure 11. Charged functioning characteristic at P=1 MW](image)

### Table 3. Values of the electric parameters in charged functioning mode for P=2 MW

| Time | Values of the electric parameters |
|------|-----------------------------------|
| t    | f [Hz] | P [MW] | Q [Mvar] | cos φ | U<sub>line</sub> [V] | I [A] | U<sub>exG</sub> [V] | U<sub>exEx</sub> [V] | I<sub>exEx</sub> [A] |
| [s]  |       |       |         |       |        |       |       |        |         |
| 1    | 50.01 | 1.98 | 3.69  | 0.47  | 6321.88 | 252.07 | 134.42 | 36.875 | 11.98   |
| 2    | 50.01 | 1.98 | 3.36  | 0.51  | 6306.9 | 235.2 | 129.41 | 35.165 | 11.37   |
| 3    | 50.01 | 1.98 | 3.3  | 0.52  | 6302.59 | 231.67 | 128.17 | 34.653 | 11.24   |
| 4    | 50.01 | 2.01 | 2.76  | 0.59  | 6278.49 | 205.93 | 120.07 | 31.524 | 10.34   |
| 5    | 50.01 | 2.01 | 2.64  | 0.6  | 6274.78 | 200.58 | 118.4 | 31.073 | 10.16   |
| 6    | 50.01 | 2.01 | 2.13  | 0.69  | 6246.18 | 177.64 | 110.86 | 28.953 | 9.39    |
| 7    | 50.01 | 2.01 | 2.04  | 0.7   | 6240.82 | 174.27 | 109.62 | 28.561 | 9.26    |
Figure 12. Charged functioning characteristic at $P=2$ MW

Table 4. Values of the electric parameters in charged functioning mode for $P=3$ MW

| Time | $t$ [s] | $f$ [Hz] | $P$ [MW] | $Q$ [Mvar] | $\cos \varphi$ [-] | $U_{\text{line}}$ [V] | $I$ [A] | $U_{\text{exG}}$ [V] | $U_{\text{exEx}}$ [V] | $I_{\text{exEx}}$ [A] |
|------|---------|---------|----------|-----------|---------------------|----------------------|--------|------------------|------------------|---------------------|
| 1    | 50.01   | 3.21    | 0.48     | 0.99      | 6145.75             | 203.94               | 93.03  | 24.077           | 7.74             |
| 2    | 50.01   | 3.21    | 0.48     | 0.99      | 6151.16             | 203.3               | 93.56  | 24.359           | 7.78             |
| 3    | 50.01   | 3.18    | 1.77     | 0.87      | 6221.38             | 223.33               | 112.54 | 30.174           | 9.51             |
| 4    | 50.01   | 3.15    | 3.18     | 0.71      | 6289.11             | 271.67               | 132.52 | 36.753           | 11.68            |
| 5    | 50.01   | 3.12    | 3.66     | 0.65      | 6316.27             | 291.65               | 140.49 | 39.857           | 12.62            |
| 6    | 50.01   | 3.09    | 4.17     | 0.59      | 6344.93             | 313.1               | 147.41 | 42.152           | 13.55            |
| 7    | 50      | 3.09    | 4.2      | 0.59      | 6343.09             | 313.29               | 147.83 | 42.322           | 13.59            |

Figure 13. Charged functioning characteristic at $P=3$ MW
Table 4. Values of the electric parameters in charged functioning mode for P=4 MW

| Time | f  | P  | Q  | cos φ | U_{line} | I  | U_{exG} | U_{exEx} | I_{exEx} |
|------|----|----|----|-------|----------|----|---------|----------|----------|
| [s]  | [Hz] | [MW] | [Mvar] | [-] | [V] | [A] | [V] | [A] | [V] |
| 1    | 49.99 | 4.35 | 3.96 | 0.74 | 6333.99 | 355.42 | 149.64 | 42.539 | 13.77 |
| 2    | 49.99 | 4.35 | 3.12 | 0.81 | 6287.11 | 326.23 | 136.48 | 37.236 | 12.08 |
| 3    | 49.99 | 4.38 | 2.79 | 0.84 | 6272.28 | 317.42 | 132.24 | 35.638 | 11.56 |
| 4    | 50   | 4.38 | 2.58 | 0.86 | 6257.94 | 311.34 | 128.69 | 34.278 | 11.15 |
| 5    | 49.99 | 4.38 | 1.56 | 0.94 | 6208.8  | 288.62 | 114.4  | 29.698 | 9.63  |
| 6    | 49.99 | 4.41 | 0.21 | 1    | 6142.25 | 277.7  | 96.34  | 24.37  | 7.96  |
| 7    | 49.99 | 4.38 | 0.12 | 1    | 6130.31 | 277.71 | 96.64  | 24.733 | 7.93  |

Figure 14. Charged functioning characteristic at P=4 MW

Table 5. Values of the electric parameters in charged functioning mode for P=5 MW

| Time | f  | P  | Q  | cos φ | U_{line} | I  | U_{exG} | U_{exEx} | I_{exEx} |
|------|----|----|----|-------|----------|----|---------|----------|----------|
| [s]  | [Hz] | [MW] | [Mvar] | [-] | [V] | [A] | [V] | [A] | [V] |
| 1    | 49.99 | 5.22 | 0.78 | 0.99 | 6168.37 | 331.38 | 112.79 | 30.208 | 9.42 |
| 2    | 49.97 | 5.19 | 2.22 | 0.92 | 6241.46 | 348.72 | 132.06 | 36.292 | 11.48 |
| 3    | 49.98 | 5.19 | 2.91 | 0.87 | 6279.52 | 364.8  | 141.7  | 40.244 | 12.67 |
| 4    | 49.98 | 5.16 | 3.51 | 0.83 | 6311.05 | 380.61 | 150.56 | 43.408 | 13.81 |
| 5    | 49.98 | 5.13 | 3.81 | 0.81 | 6319.09 | 389.31 | 154.66 | 45.252 | 14.36 |
| 6    | 49.98 | 5.13 | 4.14 | 0.78 | 6338.88 | 400.51 | 159.6  | 47.387 | 15.07 |
| 7    | 49.98 | 5.16 | 4.23 | 0.77 | 6347.36 | 404.24 | 160.84 | 47.531 | 15.26 |
2.4 Measurement the electric parameters at charge surges for $P=5.7 \text{ MW}$

In this case, the respective electrical parameters were measured vibration (Figure 16). The variation of electrical parameters for a total of 17 tests is given in Table 6 and in Figure 13.

Table 6. The electric parameters variation in charge surges at $P=5.7 \text{ MW}$

| Nr. crt. | I [A] | P [MW] | Q [Mvar] | $U_{\text{line}}$ [V] | $U_{\text{exG}}$ [V] | $U_{\text{exEx}}$ [V] | $I_{\text{exEx}}$ [A] |
|---------|-------|--------|----------|------------------|-----------------|-----------------|-----------------|
| 1       | 605.58| 5.73   | 3.18     | 6297.12          | 150.55          | 42.794          | 13.71           |
| 2       | 605.37| 5.73   | 3.18     | 6296.49          | 150.58          | 42.855          | 13.71           |
| 3       | 605.58| 5.73   | 3.18     | 6295.51          | 150.6           | 42.685          | 13.71           |
| 4       | 605.87| 5.73   | 3.18     | 6292.99          | 150.5           | 42.8            | 13.71           |
| 5       | 606.11| 5.73   | 3.18     | 6292.58          | 150.57          | 42.798          | 13.71           |
| 6       | 607.06| 5.73   | 3.18     | 6292.27          | 150.57          | 42.817          | 13.71           |
| 7       | 606.35| 5.73   | 3.18     | 6294.29          | 150.6           | 42.873          | 13.71           |
| 8       | 569.75| 5.07   | 2.82     | 6429.98          | 150.32          | 29.096          | 13.45           |
| 9       | 460.1 | 3.33   | 1.83     | 6772.53          | 109.53          | -12.36          | 9.94            |
| 10      | 312.48| 1.53   | 0.84     | 6913.14          | 63.47           | -25.12          | 5.82            |
| 11      | 0.22  | 0      | 0        | 6839.79          | 17.27           | -37.95          | 1.74            |
| 12      | 0.22  | 0      | 0        | 6279.36          | -0.19           | 0.936           | 0.22            |
| 13      | 0.22  | 0      | 0        | 5669.69          | -0.16           | 1.013           | 0.22            |
| 14      | 0.23  | 0      | 0        | 5037.49          | -0.14           | 1.017           | 0.22            |
| 15      | 0.22  | 0      | 0        | 4409.26          | -0.15           | 1.02            | 0.22            |
| 16      | 0.22  | 0      | 0        | 3807.45          | -0.13           | 1.01            | 0.22            |
| 17      | 0.22  | 0      | 0        | 3250.15          | -0.2            | 1.016           | 0.22            |
3. Experimental measurement into operation

Into operation of the hydro aggregate, were made following tests and measurements: tests under idle mode respectively tests under load.

3.1. Tests under idle mode

For this type of tests, were certain operating conditions with the generator disconnected from the network. Besides vibrations analysis, following electrical parameters were measured depending on the rotor rotation, denoted by n: line voltage generator $U_{\text{line}}$; phase voltage $U_{\text{phas}}$; $U_{\text{excG}}$ excitation voltage generator; $U_{\text{exEx}}$ excitation voltage excitation and the excitation current exciter $I_{\text{exEx}}$. The registration of these parameters is shown in Figure 14 respectively in Tables 7 and 8.
Table 7. Parameters measured at steady idle excited

| Nr. | n [RPM] | U_{line} [V] | U_{exG} [V] | U_{exEx} [A] | I_{exEx} [V] |
|-----|---------|--------------|-------------|--------------|-------------|
| 1   | 166.69  | 6893.26      | 102.14      | 26.65        | 5.79        |
| 2   | 166.61  | 6897.3       | 101.99      | 26.66        | 5.79        |
| 3   | 166.78  | 6901.96      | 101.96      | 26.55        | 5.79        |
| 4   | 166.61  | 6901.37      | 102         | 26.64        | 5.79        |
| 5   | 166.69  | 6897.9       | 101.92      | 26.64        | 5.79        |
| 6   | 166.61  | 6897.84      | 102.06      | 26.73        | 5.79        |
| 7   | 166.61  | 6899.21      | 102.05      | 26.72        | 5.79        |
| 8   | 166.61  | 6898.2       | 101.96      | 26.58        | 5.79        |
| 9   | 166.7   | 6897.6       | 101.98      | 26.73        | 5.79        |
| 10  | 166.45  | 6897.4       | 102.25      | 26.85        | 5.8         |
| 11  | 166.61  | 6901.85      | 101.95      | 26.63        | 5.8         |
| V.  | 166.63  | 6898.54      | 102.02      | 26.67        | 5.79        |
| Medie |      |              |             |              |             |

Table 8. The variation of measured values during transient excitation

| Nr. | n [RPM] | U_{line} [V] | U_{exG} [V] | U_{exEx} [A] | I_{exEx} [V] |
|-----|---------|--------------|-------------|--------------|-------------|
| 1   | 166.69  | 164.66       | 2.06        | 1.048        | 1.08        |
| 2   | 166.61  | 701.42       | 24.8        | 8.892        | 1.85        |
| 3   | 166.78  | 2074.39      | 37.6        | 8.651        | 2.49        |
| 4   | 166.61  | 2792.1       | 35.13       | 9.367        | 2.62        |
| 5   | 166.69  | 3170.12      | 45.34       | 12.26        | 2.97        |
| 6   | 166.61  | 4240.15      | 53.5        | 14.056       | 3.46        |
| 7   | 166.61  | 5285.17      | 71.06       | 19.134       | 4.22        |
| 8   | 166.61  | 6146.65      | 86.26       | 22.015       | 4.95        |
| 9   | 166.7   | 6357.64      | 88.25       | 22.917       | 5.1         |
| 10  | 166.45  | 6421.1       | 89.88       | 23.023       | 5.18        |
| 11  | 166.61  | 6612.04      | 96.5        | 25.613       | 5.47        |
| V.  | 166.63  | 3996.85      | 57.3        | 15.179       | 3.58        |
| Medie |      |              |             |              |             |

3.2. Tests under load

For this type of testing, were certain operating conditions with the generator disconnected from the network. Besides vibrations analysis, following electrical parameters were measured depending on the rotor rotation, denoted by n:
- line voltage generator U_{line};
- phase voltage U_{phaz};
- U_{exG} excitation voltage generator;
- U_{exEx} excitation voltage excitation;
- the excitation current exciter I_{exEx},
- active P and reactive Q power respectively the current stator I.

The registration of these parameters is shown in figure 15 respectively in Tables 9 and 10:
Figure 15. Variation of the parameters in excited and stable modes at charged functioning for $P=1.77$ MW

Table 9. Variation of the measured parameters at charged stable functioning for $P=5.6$ MW

| Nr. | n [RPM] | $U_{\text{line}}$ [V] | $I$ [A] | $P$ [MW] | $Q$ [Mvar] | $U_{\text{ExG}}$ [V] | $U_{\text{ExEx}}$ [V] | $I_{\text{ExEx}}$ [A] | $I_{\text{ExEx}}$ [A] |
|-----|---------|----------------------|--------|---------|-----------|----------------|----------------|----------------|-----------|
| 1   | 166.63  | 6137.25              | 378.17 | 5.64    | 2.46      | 135.1         | 36.52          | 1.08           |           |
| 2   | 166.71  | 6129.71              | 376    | 5.64    | 2.34      | 133.54        | 36.291         | 1.08           |           |
| 3   | 166.63  | 6124.6               | 374.49 | 5.67    | 2.25      | 132.24        | 35.639         | 1.08           |           |
| 4   | 166.63  | 6119.6               | 372.79 | 5.67    | 2.16      | 131.24        | 35.561         | 1.08           |           |
| 5   | 166.63  | 6113.93              | 372.37 | 5.67    | 2.07      | 130.68        | 35.329         | 1.08           |           |
| 6   | 166.63  | 6111.16              | 371.25 | 5.7     | 2.01      | 129.35        | 34.415         | 1.08           |           |
| 7   | 166.47  | 6101.53              | 369.71 | 5.7     | 1.89      | 127.77        | 33.958         | 1.08           |           |
| 8   | 166.46  | 6100.4               | 367    | 5.7     | 1.77      | 125.96        | 33.285         | 1.08           |           |
| 9   | 166.63  | 6094.59              | 364.01 | 5.67    | 1.68      | 124.72        | 33.281         | 1.08           |           |
| 10  | 166.79  | 6089.96              | 363.81 | 5.67    | 1.59      | 124.04        | 32.962         | 1.08           |           |
| 11  | 166.46  | 6086.13              | 363.17 | 5.67    | 1.53      | 123.12        | 32.464         | 1.08           |           |
| 12  | 166.46  | 6084.27              | 361.36 | 5.67    | 1.41      | 121.45        | 31.866         | 1.08           |           |
| 13  | 166.63  | 6076.34              | 359.9  | 5.64    | 1.32      | 120.07        | 31.663         | 1.08           |           |
| 14  | 166.79  | 6071.79              | 358.41 | 5.64    | 1.23      | 119.27        | 31.43          | 1.08           |           |
| 15  | 166.63  | 6064.76              | 358.41 | 5.67    | 1.14      | 117.84        | 30.735         | 1.08           |           |
| 16  | 166.46  | 6063.82              | 357.92 | 5.67    | 1.08      | 117.38        | 30.995         | 1.08           |           |
| 17  | 196.21  | 6065.07              | 356.96 | 5.64    | 1.02      | 116.31        | 29.961         | 1.08           |           |
| 18  | 166.63  | 6065.97              | 355    | 5.64    | 0.93      | 114.97        | 29.835         | 1.08           |           |
| 19  | 166.17  | 6063.48              | 354.14 | 5.67    | 0.78      | 112.41        | 28.642         | 1.08           |           |
| 20  | 166.71  | 6050.12              | 353.93 | 5.67    | 0.63      | 110.9         | 29.167         | 1.08           |           |
| V. Medie | 168.07 | 6090.72              | 364.44 | 5.67    | 1.56      | 123.42        | 32.70          | 1.08           |           |
Table 10 presents the variation in parameters for different values of active power: \( P=1.6 \div 5.6 \text{ MW} \).

| Putere \([\text{MW}]\) | \(n\) \([\text{RPM}]\) | \(U\) \([\text{V}]\) | \(I\) \([\text{A}]\) | \(P\) \([\text{MW}]\) | \(Q\) \([\text{Mvar}]\) | \(U_{\text{exG}}\) \([\text{V}]\) | \(U_{\text{exEx}}\) \([\text{V}]\) | \(I_{\text{exEx}}\) \([\text{A}]\) |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 1.6            | 167.8          | 6111.33        | 231.77         | 1.68           | 3.36           | 127            | 34.89          | 1.08           |
| 2.6            | 166.7          | 5985.43        | 174.68         | 2.85           | -0.24          | 81.79          | 21.57          | 1.08           |
| 3.6            | 166.7          | 6203.75        | 336.3          | 3.84           | 3.96           | 145.99         | 42.2           | 1.08           |
| 4.6            | 166.6          | 6004.45        | 308.66         | 5.01           | 0.06           | 98.07          | 25.35          | 1.08           |
| 5.6            | 166.7          | 6022.65        | 352.41         | 5.67           | 0.06           | 105.63         | 27.47          | 47.28          |

4. Conclusions
The voltage in no load mode, depending on the exciter excitation current increases approximately linearly.

For different power generator connected to the network, its observe the change of the excitation current in the rotor winding, determining the electrical parameters from the system under load.

Stator current regime under load depending on the exciter excitation current increases linearly and power factor depending on the exciter excitation current decreases linearly.

The regime under load there is a tendency to standardize the electrical parameters.

Under rid of pregnancy there is a rotor dynamics appropriate behavior during the transitional arrangements for over speed.

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