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Valentin Nedelea, Ionel Dragomirescu, Augustinov Ladislau, Cosmin Laurian Ungureanu

Ballast Load Control of Turbine-Generator Sets in the Micro-Hydro Range with a Turbine that has no Flow Regulating Value

This paper presents the effects of voltage and frequency variation on users load supplies from electrical supply system generated from small micro-hydro plants. Induction generators operate as stand-alone self excited by capacitors and turbine has no flow regulating valve. Many conventional and non conventional approaches are described to govern turbine-generator set to ensure a steady frequency and voltage level. A load controller increases or decreases a ballast load connected across the generator as the user load varies, to keep frequency and voltage variation in standard limits. To design a controller for self excited induction generator, researches were performed on asynchronous generator with double winding stator to analyse steady state open loop behaviour. The results on the behaviour of the unregulated turbine (DC motor) – generator system was presented.

Keywords: *induction generator, voltage and frequency control, ballast load.*

1. Introduction

Ordinary consumers connected to the electricity network to which the micro-hydro plants are connected, are adversely affected by the fluctuations of voltage and frequency control over certain limits. For example, a surge of only 5% reduces the lifetime of a light bulb filament at 50%, a drop in voltage greater than 25% pull out of the fluorescent lamps and running a surge 10% may cause an increase in heating electric radiators with 21%, which leads to a decrease of their life.

These situations occur because the turbine-generator group in power plants, does not contain adequate equipment for adjusting those parameters of the network, in terms of equipping power at low cost. The means necessary to avoid large fluctuations of voltage and frequency are: endowment of turbine flow regulator that can be mechanical, hydraulic or electrical and electronic and the generator is fitted with automatic voltage regulator.

In this situation, the turbine-generator can operate with the power of a fixed charge or with the change of electrical power. Power is constant by opening the valve turbine, sufficiently to achieve the required voltage and frequency. When power demand is not high, the valve closes and the supply of electricity is interrupted. A variant of this mode of operation is that when you use two connection ways of the consumers using two switches. So, when lighting consumers are not required, the lighting is off and in their place, there are other consumers of similar power, for example the water heater. In this way is kept a constant load on the generator. Precision frequency to this mode of operation is within ± 10%. In the event of a change of loading of the turbine-generator group the electric charge of the generator can be manually or automatically adjusted in order to maintain the network within certain parameters. Manual change of the load requires the presence of an operator. If the flow through turbine remains constant, the load imposed on the Builder should remain fairly constant to prevent significant variations of the voltage and frequency on the network. In this case, a load generator should be connected to the terminals of the ballast to be increased or decreased manually according to the variation of the loading of the generator. Ballast load, in which, in this case is dissipated some of the energy produced at the generator terminals, can be a group of incandescent lamps or heaters items in air or water. By means of a bridge, the operator can monitor the revolution group so that the task to be added to the ballast or disengaged when needed. But any system of manual checking of the turbine is vulnerable because the turbine is a machine capable of being very sensitive to accelerate out of the situation of gear speeds to increased packing time in one second, in which case the failure can occur if the electric charge is cancelled.

Effects of packing can be minimized by choosing the point of operation of the turbine on the descending curve of the turbine characteristic P = f (n) (power depending on speed) or entry into the installation of a hydraulic turbine or mechanical mechanism for reducing packing revolution. Normally, the generator coupled to turbine generates a frequency of 50 Hz at a turbine speed governors corresponding to the point of operation with maximum power and efficiency as shown in Figure 1.a.

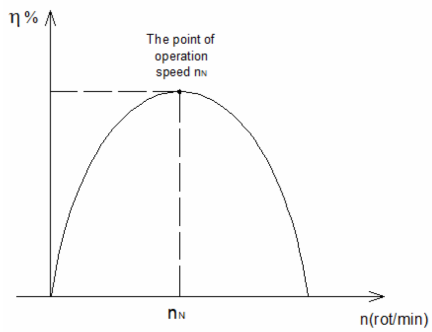

Figure 1.a.

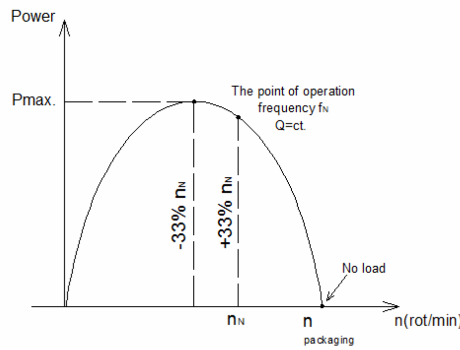

Figure 1.b.

If the electric charge of the builder is aborted, the turbine without tuning gear shall be packed up to a speed governor about two times the nominal speed of the Builder. The generator cannot work a long time in this gear and breaks down.

You can change the gear ratio between the turbine and generator so that the frequency of operation needed to be generated for example, when the turbine is at speeds between nominal and half revolutions r.p.m. packaging as seen in Figure 1.b. thus, between zero and the maximum load is between revolution variation ± 30%.

This variation of the revolution might be too broad, but it allows the use of the full capacity of the power plant without any manual control and without the risk of failure.

To avoid excessive increase of the tension, an automatic voltage regulator is necessary. The turbine, also must be able to operate continuously in close-packing revolution.

Automatic change of the load is represented schematically in Figure 2, for an asynchronous turbine-generator group in a micro - hydropower plant operating on an isolated network. Generator operates self-excitedly receiving magnetization reactive power of a battery of capacitors connected to power.

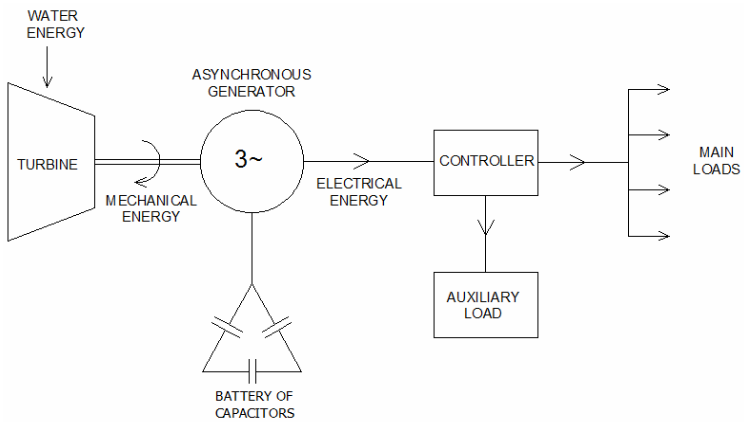

Figure 2. System configuration

The micro-hydro generator can be used to supply electricity to isolated communities, a given generator being connected to power only by capacitors, if a compromise is accepted between quality and price of the energy cost of electrical equipment in micro-hydro power plants. The use of a controller specialized in connection with a load of ballast for the dissipation of energy produced by the generator in order to increase the quality of energy delivered to consumers incurs a higher cost price.

Controller in Figure 2 solves the problem of adjustment at the same time of the revolution and making use of frequency characteristic of turbine power-gear drive with power-gear of the generator.

In principle the controller detects the voltage output of the generator that controls the variation in the amount of power sent to ballast load. If the voltage increases due to, for example a decrease in consumption of electricity on the network, adjust speed turbine and generator increase the voltage at the terminals. Then the controller detects the growth and increased power to send a ballast load.

Thus, it is increased loading of the turbine and generator and the speed, the frequency and the voltage are reduced, at the level you want. Also, the controller recognizes the inductive consumers that connect on the network, which should be supplied, provided the power factor is not less than 0,8 inductive. This is achieved by limitedly raising the frequency when such consumers are supplied, and by effectively increasing the capacitive reactance corresponding to the excitation capacitors of the generator by supplying magnetization reactive energy needs of both for the generator and for the correction of the inductive power factor of consumers.

An important disadvantage of asynchronous generator embedded network isolated voltage adjustment is with smaller effects. Even when trained with a constant speed governor, the output voltage decreases rapidly, increasing electrical load. On the other hand, the voltage is much more dependent on the revolution with which only a synchronous generator is trained. This is evidenced by research conducted in the Laboratory of Testing Equipment at the Eftimie Murgu University of Resita.

2. Results of measurements

From experimental data resulting from measurements of the asynchronous self excited generator, with auxiliary winding on the stator, change in voltage and frequency variation across the generator produced by load (resistive) is shown in the diagrams in figure 3 and figure 4.

2.1. Operation with variable load of an asynchronous generator with double winding stator.

2.1.1. Operation with winding unpowered control.

The amount of capacity on the phase of the excitation capacitors connected in delta is $C_{\Delta} = 17\mu F$.

Table 1

f_g[Hz]	P_g[W]	U_{0g}[V]	U_g[V]	I_g[A]	I_c[A]	I_s[A]
48,5	225	285	217	1,92	1,92	0,21
49		300	250	2,32	2,32	0,22
48,5	450	285	156,6	1,47	1,45	0,41
49		300	215	2,02	1,46	0,40

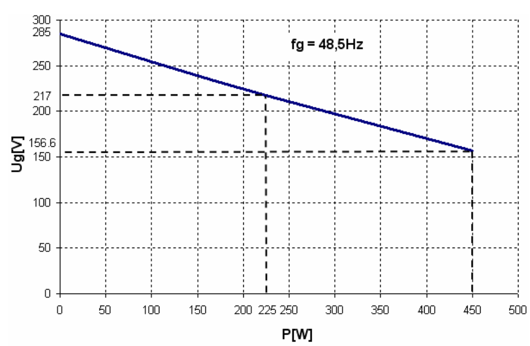

Figure 3. Variation of voltage at the generator terminal with load at 48,5Hz

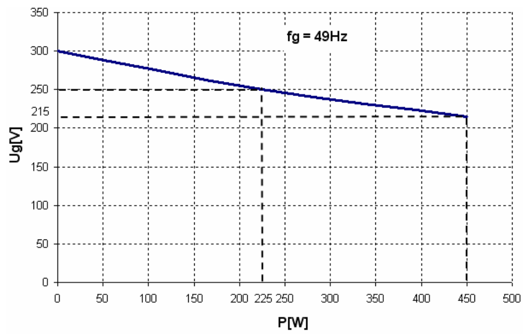

Figure 4. Variation of voltage at the generator terminal with load at 49Hz

2.1.2. Operation with winding control powered from frequency converter

- Frequency control voltage value: $f_{reg} = 155Hz;$
- The value of the voltage supply winding control: $U_{reg} = 30V \div 40V \div 50V;$
- Voltage at the terminals of the generator at no load variation of voltage adjustment (Table 2);

Table 2

f_g[Hz]	f_{reg}[Hz]	U_{reg}[V]	U_{g0}[V]	C[μF]
48,89	155	50	301	17
49,65		40	300	
49,52		30	297	

Voltage at the terminals of the generator with load variation of voltage adjustment is shown in the diagrams in figures 5, 6 and 7.

Table 3

f_g[Hz]	f_{reg}[Hz]	P_g[W]	U_g[V]	U_{reg}[V]	I_g[A]	I_c[A]	I_s[A]
48,68	155	225	230	30	2,09	2,08	0,22
48,9			240,5	40	2,2	2,23	0,23
49,34			262	50	2,42	2,41	0,26
48,65	155	450	163,5	30	1,53	1,5	0,41
48,84			183,5	40	1,71	1,65	0,42
49,53			238	50	2,23	2,2	0,48

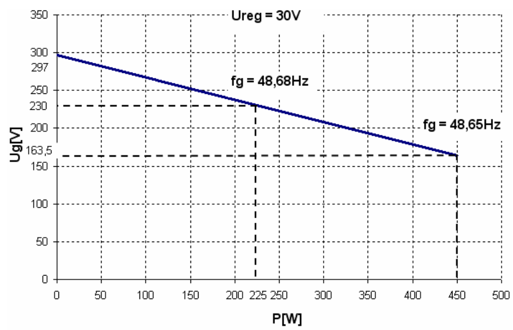

Figure 5. Variation of voltage at the generator terminal with load to voltage supply winding control U_{reg}=30V

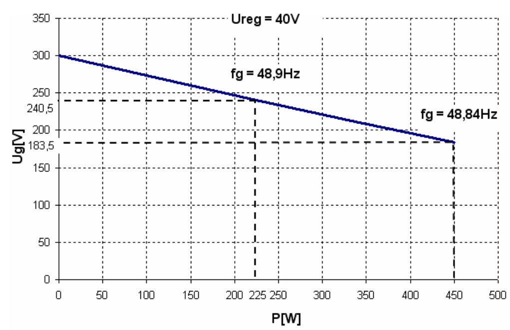

Figure 6. Variation of voltage at the generator terminal with load to voltage supply winding control U_{reg}=40V

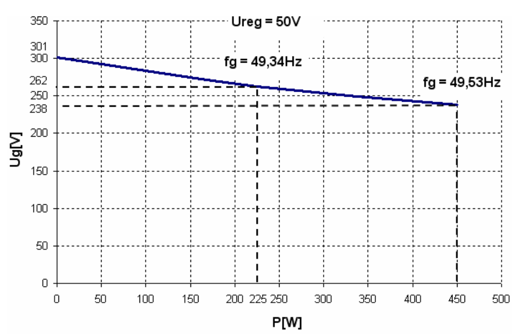

Figure 7. Variation of voltage at the generator terminal with load to voltage supply winding control U_{reg}=50V

3. Conclusions

Using the proposed approach based on ballast resistance, it is possible to control voltage and frequency of the self-excited induction generator operated as a stand alone under varying load conditions.

The method needs a designed controller based on measurements about unregulated behaviour of the induction generator with double winding stator.

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Addresses:

- Eng. Valentin Nedelea, , "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, v.nedelea@uem.ro;
- Eng. Ionel Dragomirescu, I.J.J. Caras- Severin, Str. Erou Jandarm Nicolae Marcu, Nr. 1, Reşiţa, ioneldragomirescu@yahoo.com;
- Dr.eng. Ladislau Augustinov , "Eftimie Murgu" University of Reşiţa, Piaţa Traian Vuia, nr. 1-4, 320085, Reşiţa, l.augustinov@uem.ro;
- Eng. Cosmin Laurian Ungureanu, SC Enel Distributie Banat SA, Bd. A.I. CUZA, Nr. 42, Reşiţa, ungureanu.cosmin@enel.ro.