American-Eurasian Journal of Scientific Research 8 (3): 104-108, 2013
ISSN 1818-6785

DOI: 10.5829/idosi.aejsr.2013.8.3.1116

Selection of Generator for the Micro Hydro Power Plant

Azhumakan Zhamalovich Zhamalov Alaibek Dhumabekovich Obozov,
Murat Merkebekovich Kunelbayev Ruslan Isaev and Balzhan Abylkanovna Chakenova

Kazakh State Women Pedagogical University,
Kazakh State Teacher Training University, Alamaty city, Kazakhstan

Abstract: Based on the analysis of asynchronous and synchronous generators we can conclude that for the consumers of a small electric power, as the power sources, it will be appropriate to the use of the asynchronous generators, because they satisfy most requirements imposed by the consumers: a high quality output voltage, a low mass, a relatively low cost, a high reliability, a simple design and an easy maintenance. In present paper we propose to use a three-phase asynchronous generator with a squirrel cage rotor for the general industrial use as a generator. Domestic industry produce epy asynchronous generators in a wide variety by the form factor, capacity, rotation speed, according to the well established technologies all that allows us to create the asynchronous generators on their basis, which are combined with the different drive motors. The synchronous generators have a complex management system and the environmental conditions have a significant impact on their operation, so that it is required to conduct the regular qualified maintenance. A capacity of the designed power supply has the great influence on the selection of generator. For example, the advantages of asynchronous machines by mass and cost manifest themselves in the power range from a fraction of kW to 100 kW. With increasing of the power plant capacity of more than 100 kW, the capacity of the excitement capacitors increases significantly and the mass and dimension indices of the generator itself become comparable to the synchronous machines.

Key words: Micro hydro power plant · Three phase asynchronous generator · Output voltage · Square-cage rotor

INTRODUCTION

The micro-HPP is one of the most popular renewable sources of energy in the developing countries. Most of the Micro-HPPs work in the isolation mode of power supply in the local countryside, where the population is very small and rarely distributed. Expansion of the system network is not financially possible due to the high investment costs required for the transmission line. The small hydroelectric power systems (SHPS) are the relatively small power sources that are suitable in many cases for the individual consumers or the groups of users that are independently supplied from the electrical network.

There are two main types of generators that are used for the hydropower production: synchronous or asynchronous generators. The synchronous generators are the main types of generators that are used in large scale of the energy production. When the output power levels are generally less than 10 MW, the asynchronous generators are widely used. In the production of generators are also preferred the asynchronous generators, because they can operate at different speeds with a constant frequency, are cheap and require less maintenance as compared to the synchronous type. Both of these generators have the ability to use the network connection or just work in the autonomous mode [1].

The asynchronous generators are generally suitable for the micro hydropower generation [2]. The offered asynchronous generator has many advantages over the ordinary synchronous generator as a source of isolated power [3]. Reduction in costs per unit, a durability, the reduced size, the lack of a separate DC power supply and

Corresponding Author: Kunelbayev, Kazakh State Women Pedagogical University, Kazakh State Teacher Training University, 050000, Republic of Kazakhstan, Alamaty city, Aiteke bi, 99.

an ease of maintenance, the self-protection against the severe overloads and short circuits be the key advantages of the asynchronous generators [4, 5].

The micro-HPP contains the mandatory elements such as the energy converter of water into the mechanical energy of the rotational shaft movement of the electro generator, an electric generator, a stability system of the output voltage and a number of elements, the presence and the design of which depends on the type and features of the plant: the specific hydraulic structures shut-off valves, dummy loads and etc [6].

The main direction in the modern automated micro-HPPs creation is the application of the unregulated hydraulic engines and the increase of requirements to devices for the electric power generating and the stabilization of its parameters. In this paper, the three-phase asynchronous squirrel-cage motor with a rotor and the capacitor self-excited is used as an electric generator of the micro-HPP. The hydraulic engine is an overshot wheel.

The generator is the most important element of the electrical equipment for the autonomous power supply system. Besides the basic purpose that is an electric power generating, it performs the certain functions on stabilization or the monitoring of processes that characterize the quality of electric energy. Therefore one of the requirements for the autonomous generator of the power plant is the handling. The constructive performance of the generator shall ensure the possibility of its operation in the open air with a high degree of reliability over a long time and a low market value. The most common in the AC A-plant got both the synchronous and the asynchronous EMG [7-10].

Until recently, the synchronous generator (SG) was the most widely used source of the AC electric power to supply the autonomous objects. The SGs' characteristic feature is in the fact that they do not require an additional reactive power source to create a working magnetic flux. Synchronous machines excitation is carried out by means the special windings to be connected to a DC power source, or from the permanent magnets, depending on a design. The excitation power does not exceed a few percent of the SG capacity [7, 8]. The SG classic design envisages the anchor winding placement on the stator and the excitation winding - on the rotor of the generator. The excitation current is supplied to the rotor winding through the slip rings and that is a disadvantage of the classical alternate design. An inverted design, where a rotor with the excitation winding is a motionless and the stator rotates, is rare in the synchronous machines due to the complexity of the current lead to the AC rotating winding.

Contactless options of the SG with an electromagnetic excitation can be constructed in various ways:

- Using of contactless excitation systems for a classical design;
  - Using of special generators' designs - an inductor-type;
  - With an externally closed magnetic circuit and etc. [6].

At the autonomous operating mode the SG is excited from the output voltage of anchor winding through the rectifier. The initial self-excitation of the SG is carried out on the same circuit due to the residual magnetic flux of machine. The frequency of the SG generated alternating voltage is determined only by its rotational speed and the amplitude also depends on the current in the excitation winding. Therefore, the AEES construction by the SG output parameters is a complex task.

The ACS of the synchronous generator, which is part of AEES, shall perform the following functions:

- To ensure the self-excitation of the synchronous generator at a given frequency of its rotation;
- To supply the excitation winding from the AC source by the voltage value at the changing frequency;
- To adjust the SG input voltage based on a specified law, when you change the rotational frequency, the value and the nature of load;
- To form the excitation when you turn on the consumers, whose capacity is commensurate with the generator capacity;
- To limit the value and the duration of voltage deviations from steady-state value within the specified limits [2, 4, 7-8].

The promising types of generators for the AEES are the SG with a contactless excitation system and the SG with the permanent magnet excitation. Disadvantages of the first type SG are the complexity of design, the increased by the introduction of inertance an inertial relaxation circuit agent into the control loop. The speedup of such systems is achieved by applying the controlled valves on the rotor, what complicates the ACS and the generator's design and increases the cost of AEES.

Table 1:

Generator type	Power, kW	Weight, kg	Cost, rub.
OS5-51Y2	4,0	118	27900
OS-71-Y2	16,0	263	57600
OS-72-Y2	30,0	349	69800
ESS5-61-4Y2	8,0	160	37860
ESS5-62-4Y2	12,0	189	44800
ESS5-81-4Y2	20,0	349	57600
ESS5-82-4Y2	30,0	420	69400
ESS5-91-4Y2	50,0	490	73200
ESS5-92-4Y2	60,0	495	78900
ESS5-93-4Y2	75,0	544	89600
GS-8	8,0	150	52950
GS-16	16,0	204	66650
GS-30	30,0	288	75950
GS-60	60,0	424	100200

The synchronous generators with the magneto electric excitation have the following disadvantages: an absence of the direct method of the voltage control, due to the complexity of the excitation flux changing from the permanent magnet; a scatter of the magnets features; a dependence of the technical and economic parameters from the magnetic permanent properties. For a rough estimation of the SG technical and economic parameters, the characteristics of serial machines that are used as sources of the three-phase AC current with frequency of 50 Hz, at a shaft rotation speed 1500 rpm / min, a voltage of 230/400 V are shown in the Table 1. The SG cost is given according to the data from the "Longbim" firm (Moscow) for the year 2006.

The characteristic feature of the asynchronous generators is their inability to produce the magnetizing current for the magnetic fields formation. Therefore, they operate in the presence of external sources of excitation. As such source can be used an electric network. When operating in the generator mode, the asynchronous machine consumes the reactive power from the network and gives the reactive power to the load.

When the AG works on the independent loading, the excitation can be achieved in two ways:

- By the powering through the slip rings of rotor winding with the currents of low frequency - an independent excitation on the rotor;
- By connecting the capacitors or the synchronous compensator in parallel to the stator windings - the stator self-excitation.

In the first case one of the main advantages of the asynchronous machines is the lost that is noncontact.

Moreover, a special low frequency power supply is necessary for the purpose of stimulation, so it complicates and raises the price of the whole system. AG with stator self-excitation has the number of positive features typical of machines with square-cage rotor, i.e. simplicity, low price, reliability, noncontact and possibility to stabilize in case of variable rotation speed of rotor.

Structurally, the simplest EMG is asynchronous self-excited generator (ASG), which is three-phase AM with square-cage rotor and excitation condensers connected parallel to its stator. Until recently the application of ASG was restrains by failed external characteristics of the machine and absence of reliable and cheap source of reactive power. Modern achievements in the field of condenser construction, semiconductor techniques and electronics, which allowed to reduce the weight, size and cost of AC condensers, set the stage for the successful solution of problems of ASG application. Specific weight of polypropylene condensers at a frequency of 50 Hz is 0.3-0.5 kg / quar, that is much less than the specific weight of AM (8-9 kg / quar). The development of devices with non-contact control of capacity using semiconductors and integrated circuits, adjustable chokes solved the problem of stabilization of the ASG output voltage.

Due to the great variety in the type of performance, power, rotation speed of relatively inexpensive, reliable in operation, serial AM, produced by the domestic industry, their use in generator mode, is an urgent task. In conjunction with the various drive motors serial AM are suitable for power generation according to quality and characteristics that meet the requirements of agricultural consumers. Table 1.8 shows the cost (according to the company "Longbim" for 2006) and the characteristics of three-phase asynchronous motors with square-cage rotors for general industrial use with a synchronous speed of 1500 rpm.

The cost of machine includes the cost of self-excited condensers. The data given in the Tables 1 and 2 shows us that the SG, compared with the ASG, have the much greater mass and cost.

Theoretical studies of autonomous power supply, carried out in recent years in our country and abroad, as well as practical experience of their use show the benefits of using ASG in them.

The AG is the only variable-pole machine with no windings on the rotor, with the electromagnetic excitation and the radial direction of the magnetic flux.

Table 2:

Motor type	Motor power, kW	Motor weight, kg	Weight of excitation condensers, kg	ASG weight, kg	Motor cost, rub.	Cost of excitation condensers, rub	ASG cost, kg	ASG active power, kW
AIR80A4	1,1	11,9	0,31	12,21	1759	213	1972	0,9
AIR 80Â4	1,5	13,8	0,43	14,23	1866	231	2097	1,2
ANR90L4	2,2	18,6	0,6	19,2	2627	267	2894	1,8
ANR100S4	3,0	25,0	0,8	25,8	3422	383	3805	2,4
AMR100L4	4,0	31,0	1,2	32,2	3632	392	4024	3,2
AIR112Ì4	5,5	49,0	1,02	50,02	4126	390	4516	4,4
ANR132S4	7,5	70,0	1,53	71,53	5070	593	5663	6,0
AIR132Ì4	11,0	83,5	2,1	85,6	6136	799	6935	9,0
AMR160S4	15,0	130	2,8	132,8	11296	1050	12346	12,0
AIR160Ì4	18,5	145	3,4	148,4	12204	1295	13499	15,0
ANR180S4	22.0	170	4,1	174,1	15266	1544	16810	17,6
AIR180Ì4	30,0	190	5,5	195,5	18636	2067	20703	24
A200Ì4	37,0	245,0	6,4	251,4	23545	2484	26029	29,6

Comparative evaluation of weight, size and energy performance of asynchronous and synchronous generators in the power range of 1-100 kW at a frequency of 50 Hz and a speed of 3000 rpm show that the total weight of AG together with a device for excitation is less than the SG in 1,3-1,4 times. Compared with the non-contact SG (e.g., inductor), the mass of AG is less in 2-3 times.

Efficiencies of AG and SG with the excitation devices are about the same. Dispersion in the secondary circuits of AG is less than in inductors of SG because of the smaller dispersing surfaces and magnetic stresses on these parts.

Weight and cost of excitation condensers, which are taken as polyethylene terephthalate condensers K73-50, were calculated by connecting the stator windings AD in the form of star and condensers – in the form of triangle. Prices for capacitors are taken in JSC "Elkod" at the end of 2005.

Along with this better distribution of losses between the rotor and stator windings is achieved, as a result the rotor heating rate is facilitated and it is possible to carry out effective removal of most of the losses in the machine through the stator.

The SG output voltage of small or medium power has significant "slotting" harmonic components due to the relatively small number of slots per pole pitch and imperfect form of the poles. This leads to a significant deviation of the output voltage from the sinusoidal.

In case of load unbalance, short-circuited bar system of magnet symmetric rotor acts as a complete damper winding of synchronous generator, so that the quality of the power generated by ASG is provided at a high level and unbalanced load conditions.

In case of short circuit in the load circuit unexcitement of AG is appeared, so there is no need to protect the generator and, therefore, the installation of additional equipment. The recovery time of voltage after the short circuit does not exceed 1 sec.

Turning of SG to the parallel operation is a complex and critical operation: it is necessary to provide equal voltage at the terminals of generators and equal frequency of generated current at the same phase sequence. At the same time, turning of SG to the parallel operation does not require complicated additional equipment and synchronization of generators requires only equalization of their frequencies and voltages. Even with the significant mismatch of rotor rotational speed of generators, the current frequency is established in the system, which is equal to the average current frequency of generators turned to the parallel operation. In this case, the excitation condensers act as filters that cut off the higher harmonics in the output voltage that contributes to the disappearance of the stress pulsation and long transients and allows getting the perfectly sinusoidal output voltage of AG. Studies of parallel operation of AG show that the amplitude of exchange oscillations of active power is about 3 times less than the amplitude of SG and transients are practically absent during increase or decrease of load [1, 2, 6, 7, 9, 10].

It should also be noted that the SG has a complex control system for its operation and it is significantly affected by environmental conditions, regular qualified maintenance is required. The choice of the generator is greatly influenced by the power of designed power supply. For example, the advantages of asynchronous machines by weight and cost are shown in the power range from a fraction of kW to 100 kW. With the increase in power of power plant by more than 100 kW, the power of excitation condensers significantly increases and the weight and size of the generator itself become comparable with synchronous machines. Therefore, it is more appropriate to use SG in stationary installations with more power [3, 5, 10].

Based on the analysis of asynchronous and synchronous generators, it can be concluded that the low power consumers should appropriately use ASG as power sources as they meet all the requirements of consumers: high quality of output voltage, light weight, relatively low cost, high reliability, simplicity of construction and maintenance. The present work recommends using three-phase AD with square-cage rotor for general industrial use as a generator of AEES.

So, on the basis of the bibliography analysis, it can be concluded that the current stage of development of autonomous power industry is characterized by a continuous increase in demand for autonomous power supplies of various power for general and special use, extension of unit power of these sources, noticeable increase in requirements for the mobility, reliability and cost-effectiveness, quality of electrical energy.

One of the solutions of this problem is the use of autonomous power plant ASG based on the serial three-phase motors with square-cage rotor for general industrial use as electric generator.

High reliability of autonomous power plants and high quality of electric energy require full automation of energy conversion process and maximum simplicity of maintenance of these plants. To solve these problems it is necessary to develop:

- Mathematical models of three-phase AD and autonomous ASG;
- Method of calculating the performance of ASG, capacity of excitation condensers, parameters of the equivalent circuits of AD; effective technical solutions for the composition and structure of the automatic stabilization parameters of electric power generated by ASG.

REFERENCES

1. Upadhayay, S., 2009. Evaluating the effectiveness of micro-hydropower projects in Nepal. San Jose State University, SHSU Scholar Works.
2. Bhatti, T.S., R.C. Bansal and D.P. Kothari (Ed.), 2004. *Small Hydro Power Systems*, Dhanpat Rai and Sons, Delhi, India.
3. Simoes, M.G. and F.A. Farret, 2004. Renewable Energy Systems: Design and Analysis with Induction Generators, *CRC Press*, New York, USA.
4. Bansal, R.C., T.S. Bhatti and D.P. Kothari, 2003. A bibliographical survey on induction generators for application of non-conventional energy systems, *IEEE Trans. Energy Conversion*, 18(3): 433-439.
5. Bansal, R.C., 2005. Three-Phase Self-Excited Induction Generators (SEIG): An Overview, IEEE Trans. Energy Conversion, 20(2): 292-299.
6. Lukutin, B.V., S.G. Obukhov and E.B. Shandarova, 2001 Autonomous power supply from the micro hydro power plant. - Tomsk: STT, pp: 12.
7. Grigorash, O.V., 1995. Present state and prospects of the asynchronous generators application in the stand-alone generation. / / Industrial Power Engineering, 3: 29-32.
8. Lukutin, B.V. and G.A. Sipailov, 1987. Using of mechanical energy from the renewable natural sources for the power supply of autonomous consumers. - Frunze: Publishing House of the "Ilim", pp: 136.
9. Equipment for the small hydropower plants / / Int. Water Power and Dam Const. -1986, 38(4): 41-50.
10. Handbook of electric machines: In 2 vol. / under the gen. editorship of I.P. Kopylov and B.K. Klokov. Vol. 1. - M.: Energoatomizdat - 1988. pp: 456.