Decentralized generation system using low cost conventional components

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Abstract

In certain areas of Brazil, a great percentage of the rural population still lives today without electric energy supply available through energy distribution networks. For these rural properties, which present a low energy demand, the voltage of already existing networks becomes an economically infeasible action. Other energy forms in properties can also be used. Among these, the ones which make use of local energy resources. This work presents the performance of a decentralized system of electric energy generation, constituting itself of a hydraulic turbine connected to an electric generator. This system has as characteristics, robustness, operation facility and the low acquisition cost of its components. The hydraulic turbine was developed to operate with constant flow and height of water fall. The electric energy generation was done, using in different moments, two generators, a synchronic and an asynchronous. The results obtained, point towards an availability of 720 W of electric power, in a permanent rate. This power is capable of supplying the basic needs for illumination, leisure, water heating and also of intensifying the local economy.

Keywords

Hydroelectric micro powerhouses. Distributed generation. Synchronic generation. Asynchronous generation.

Resumo

Em determinadas regiões do Brasil, uma grande parcela da população rural ainda hoje vive sem o fornecimento de energia elétrica através de redes de distribuição de energia. Para essas propriedades rurais, que apresentam uma baixa demanda de energia, a extensão de redes já existentes torna-se uma obra inviável economicamente. Outras formas de energização de propriedades podem ser utilizadas entre elas as que utilizam os recursos energéticos locais. Esse trabalho apresenta o desempenho de um sistema de geração descentralizada de energia elétrica constituído por uma turbina hidráulica acoplada em um gerador elétrico. Esse sistema tem por características a robustez, a facilidade de operação e o baixo custo de aquisição de seus componentes. A turbina hidráulica foi desenvolvida para operar com vazão e altura de queda de água constantes. A altura de queda de água de 2 m é obtida através da própria tubulação da turbina. A geração de energia elétrica foi feita utilizando-se, em momentos diferentes, dois geradores: um síncrono e outro assíncrono. Os resultados obtidos apontam para uma potência elétrica disponível de 720 W em regime permanente, potência essa capaz de suprir as necessidades básicas de iluminação, lazer, aquecimento de água para banho e intensificar a economia do local.

Palavras Chave

Microcentrais hidroelétricas. Geração distribuída. Geração síncrona. Geração assíncrona.

Introduction

The main objective of this paper is to present the details of an isolated system of electric energy generation, which uses a hydraulic turbine, connected to an electric generator.

For such, two prototypes were developed. One of them used a synchronic generator (KOSOW, 1986) 1986), connected to a hydraulic turbine, and specially designed for constant flow and water fall. The operation and performance of both prototypes, in different situations of load and flow, were analyzed.

Finally, a comparative analysis between both sets was done. This comparative analysis contemplates technical aspects (TORO, 1994) so as to make it possible that future users may choose between one system and another.

Preliminary Trials

Initially, the synchronic and the asynchronous generators were tested separately. For such, a DC Motor of the Electric Machinery Laboratory was used as a primary machine.

DC motor versus synchronic generator

The testing of the electric energy generation system was performed by setting it to a synchronic speed, nominal of the Synchronic Generator, and with the voltage measured, generated with no load. The voltage was adjusted to its nominal value, through the rheostat circuit of the SG field supply, making the voltage to reach 225 V.

In a second moment, the load was applied to the SG. A slight voltage fall and a strong decrease in the speed of the primary machine are observed, due to the breaking torque caused by the active load applied to the SG, demanding more power from the primary machine. In this case, from the DC Motor, so as to maintain a constant rotation.

DC motor versus asynchronous generator

The attainment of the magnetizing curve of the Asynchronous Machine (FITZGERALD; KINGSLEY; KUSKO, 1984) was obtained by maintaining the rotor blocked and increased, gradually, the voltage applied to the machine until its magnetic saturation.

From this point of saturation, the capacitive reactance value is determined and consequently the value of the capacitor set to be used in the asynchronous generation. With the capacitor set connected to the asynchronous machine stator, it is possible to achieve the excitement of the asynchronous generator and a voltage of 251 V to zero is reached. It is observed that, as the load is applied, the voltage variation becomes abrupt, demanding an adjustment.

Speed control of the asynchronous generator

The circuit developed has as an objective the control of output voltage of the asynchronous generator. This circuit has three identical microcontrollers, each one responsible for the voltage control of a phase (three phase generator, Y connection). The circuit also possesses a DC source for the other microcontrolled blocks.

The main component of the microcontrolled circuit is the PIC12F675 Microchip microcontroller, which has FLASH memory program, RAM data memory and EEPROM, analog digital converter with a 10 bits resolution, analog voltage comparative and 16 bits timer.

The circuit has a transformer, which is used for lowering the network voltage (so that the microcontroller can read it through the analog digital converter), as well as for the synchronicity to be accomplished (for the determination of the discharge angle, with the help of the analog digital converter). Each resistive load is triggered by a TRIAC, which has its trigger connected to an optocoupler which provides galvanic isolation between the microcontrolled circuit and the power circuit. This optocoupler is directly connected to the PIC.

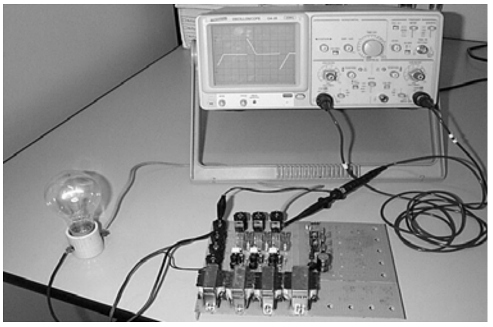


Figure 1 – Electronic voltage regulator

When the generator operates in its full power, it maintains the output voltage around 220 V (nominal voltage, between a phase and the neutral). When it operates without a load, however, this voltage reaches around 260 V, so there must be a control over this system in order for the voltage elevations not to happen. This could damage the equipments which are hooked to the electric network.

For an effective control to be taken, the generator's demanded power must be constant, more specifically with its same nominal power. In this way, a resistive load (with a value that dissipates power equal to the generator's nominal) for each phase. The power control dissipated by one of these resistors is done through the trigger angle variation of its respective phase. In case no load is imposed by the network, the PIC microcontroller will adjust the angle of the resistor triggering to 0^o (zero degree), making the dissipating power caused by it, the same as the nominal power of the generator. Otherwise, in case the network demands the maximum power from the generator, the adjusted angle will be of 180º, with no power dissipation over the resistor.

In case there was no control over the output voltage of the generator, as a network electrical equipment is removed or added (variation of the dissipating power), there would be a voltage variation through time. With control, this inconvenience Would not occur, because the microcontroller is constantly monitoring the network voltage, so on realizing that it has expanded the established limits, PIC alters its triggering angle of the resistor for the voltage to be kept in the defined operating level.

Assembly of the Trial Bench

The trials of the turbine sets and synchronic and asynchronous generators were performed at the Laboratory of Flowing Machines of CEFET-RS. It was necessary to establish the nominal conditions of the turbine performance to make it happen: water flow at the value of 76 liters per minute. For such, a reduced river model was arranged. It was projected and built in a metal structure capable of guaranteeing the support of the equipment constituents of the electric energy generation system and the water elevating station, obtaining a two meter drop of manometric column with enough stability for supporting the operators and the measuring and process control equipments, according to figure 1.

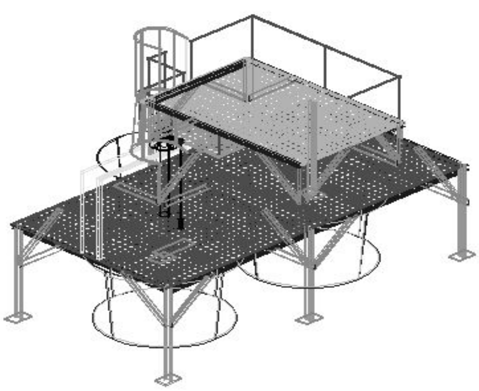


Figure 2 – Metallic structure scheme

The necessary water volume for the operation of the assemblage justifies the construction of a system of reutilization and recirculation of the liquid for an undetermined period.

The hydraulic turbine demands a positive height of one meter and thirty centimeters for its functioning and a suction of seventy centimeters, as well as to be submerged in the bailing vessel capture and to save space before releasing the liquid with the extremity submerged in a second bailing vessel.

These conditions were guaranteed using glass fiber water tanks with commercial dimensions adapted to the needs of the project. The recirculation of the liquid between the upper and lower water tanks was done through a centrifugal water pump, dimensioned only for the fluid transportation without having any addition of extra energy.

The maintenance of the rates and the conditions of inertia needed for the surface of the liquid reception forced the installment of a third water tank. This way, there were two water tanks connected to each other in the lower part and an upper water tank in which the turbine was installed.

The flowing and the level control are obtained with the help of a frequency inverter which allows the management of the flow without adding load losses and/or interfering in the flowing rate.

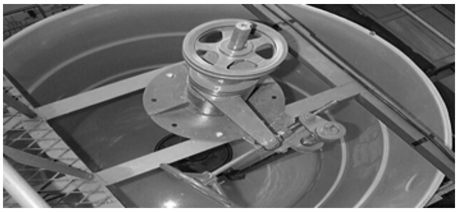


Figure 3 – Turbine assemblyFigure

Trials of the Assemblage Turbine Generator

Turbine versus asynchronous generator with voltage control

With the asynchronous machine connected to the turbine, its excitement starts through the capacitor set supply with a circuit external. A voltage in the generator terminals, with no load, reaches 253V. Secondly, a voltage control system is activated, which stabilizes voltage at the terminators of the generator at 220V.

The system (turbine and asynchronous generator) has shown itself satisfactory to work in the 720W conditions (240W per phase) presenting a voltage of 221V between phase and neutral for a rotation of 900 rpm.

A strong fall is noticed in the generated voltage and this can be explained by the rotation fall, which diminishes the frequency and consequently the value of the capacitive reactance, because the value used for the capacitor set was fixed.

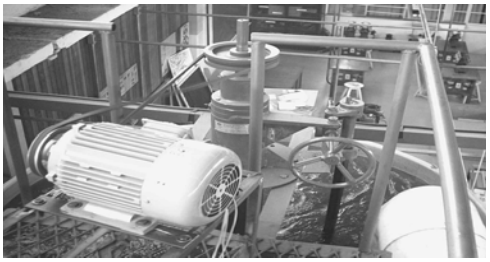
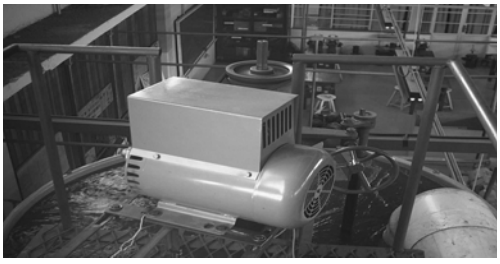


Figure 4 – Asynchronous Generator connected to the turbine

Turbine versus synchronic generator

In the trial with the synchronic generator connected to the turbine, there is no need to worry with excitation, since it presents an internal regulator. In this condition, the voltage established itself at 220 V. The satisfactory condition of the turbine equipment operation and of the synchronic generator was of 780 W with a voltage of 220 V. The rotation and voltage keep constant due to the constant rate of flow and load.



5 – Synchronic generator connected to the turbine

Conclusion

This paper presented an overview of the performance of a decentralized electric energy generation system, using a hydraulic turbine, especially designed to work with constant flow and load as well as connected to an electric generator. Two forms of electric energy generation were used: asynchronous and synchronic.

It was observed that both systems presented a similar performance, limited to the nominal power of the turbine.

The results obtained show that for small rural properties, which have a low consumption of energy, the system is capable of supplying the basic needs for illumination and leisure.

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Sistema de geração descentralizada usando componentes convencionais de baixo custo

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