Power generation

Hydropower from pumps-as-turbines

Brazil is known for its use of hydropower, but when a small, remote tourism complex in a Brazilian nature reserve needed additional power supply, a conventional hydropower solution was deemed too expensive. A more affordable option came in the form of a centrifugal pump driving an electric motor acting as a generator.

The small tourism complex in the Brazilian nature reserve is thereby generating electricity for all its power requirements from a water pump operating as a turbine. The KSB Meganorm water pump is used to produce electricity by driving an electric motor which operates as a generator. This cost-effective technology allows hydropower to be harnessed in remote locations in an environmentally responsible manner.

Brazil has access to extensive hydropower and it is almost impossible to find a location that does not feature a small waterway or rapids. However, the North East’s semi-arid areas are an exception. The country’s geography makes it difficult to supply remote settlements with electricity and it therefore makes sense to use the widely available hydropower resources to produce electricity. The use of local hydropower generators means these communities do not need to rely on diesel generators, which are associated with high fuel consumption and environmental hazards.

These types of small hydropower stations are readily available on the market, but they remain too expensive to be used by farmers in far-flung locations or remote communities. However, a far more cost-effective solution than the purchase of a small hydropower station does exist – namely, the use of a conventional and comparatively low-cost centrifugal pump as a turbine, combining it with a regular electric motor that is operated as an electricity generator.

Field-testing has shown that a centrifugal pump can operate efficiently as a turbine given appropriate inlet pressure and flow rate. In some cases, the efficiency level achieved during turbine operation exceeds that possible for regular pump operation. In order to test this type of power generation, under real operating conditions, a team from the University of Itajubá, Brazil conducted a field test in 2007 to prove the technology’s suitability for practical use.

The field test was carried out at the Fazenda Boa Esperança, located on a 211-hectare site within the Serra da Mantiqueira nature reserve in the Minas Gerais province. The Fazenda is largely dependent on ecological and nature tourism, alongside fish farming, and operates a restaurant as well as nine...
The PAT/IG project, which involved a pump used as turbine (PAT) and an electric motor as an induction generator (IG) to produce electricity at the Fazenda Boa Esperança, was undertaken in a number of stages. The first stage was to undertake a new survey of the complex in order to record all relevant topographical and hydrological data and to measure the Fazenda’s energy requirements. A topographical differential GPS with 0.04 m accuracy and a base station with 0.005 m accuracy were employed for the topographical measurements and geocoding. All of the small power station’s systems were geocoded in order to provide a reliable data set for the hydrological study.

The survey indicated that the Fazenda Boa Esperança’s hydropower station is fed from a predominantly wooded drainage zone of 36.4 km² that also features areas with steep slopes. Three hydrometric measuring sessions with flow meters also revealed that a consistent flow rate (duration 95%) of approximately 0.50 m³/s could be assumed for further planning.

In order to calculate the energy required, an inventory list of all of Fazenda’s existing electric devices and components, together with their respective power requirements was compiled. To estimate peak demand, the power requirements were calculated for times when the Fazenda is leased for events. The maximum total demand was determined to be 38.2 kW and, taking a planned extension into account, a theoretical peak demand of 43 kW was calculated.

On the basis of the maximum power requirement and the site’s total gradient, a diagram charting the relationship between output and rated flow was used to determine the flow rate required through the turbine to deliver the desired output. The flow rate for the target maximum output of 43 kW was 0.27 m³/s. This was found to be achievable during normal operation in such a manner that 60% of the water flowing through the Boa Vista River remained unaffected, allowing the rapids and fish farm ponds to be protected while using the remaining 40% for power generation.

Selection of a suitable pump for use as a turbine was performed on the basis of a method developed by J. M. Chapallaza. According to this procedure, a net gradient of 21.8 m and a rated flow of 0.27 m³/s required a pump capable of generating a head of 14.48 m and a flow rate of 0.212 m³/s. These requirements led to the selection of KSB’s Meganorm 200-250 pump designed for a nominal flow rate of 0.21 m³/s and a head of 15 m, achieving an efficiency level of 84%.

The Chapallaz procedure was also used to select the induction generator, revealing that a motor with a 55 kW output and a capacitor bank with 600 µF per phase would be required for the generator’s self-exciting. Here, a three-phase motor from WEG, with a rated voltage of 220 V and a mains frequency of 60 Hz, was chosen designed to provide a rated output of 45 kW.

A system was installed to allow control of the generator unit. The PAT’s speed control is performed via a butterfly valve upstream of the generator unit which in turn is controlled by an electronic unit. The small hydropower station was equipped with additional instrumentation which allows the PAT/IG set to be continuously monitored.

Following the installation of the new generator unit alongside the old Michell Banki turbine in the existing machinery building, some modifications were required. Both the building and the intake structure were enlarged, followed by the installation of a second discharge pipe, a protective bar screen, a new settling tank and a new desander system. The extension work also included improvements to the ventilation and lighting alongside a service access door and a manual pulley system.

The PAT system has been operating since 2007 to the owner’s full satisfaction. “We are enthusiastic about this kind of energy generation,” says Luiz Carlos B. Reis, the owner of Fazenda Boa Esperança. “In order to keep meeting our electricity demands in an ecological manner in the future, we are currently planning the installation of another PAT/IG set.”

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Figure 3. The three-phase motor from WEG with a rated voltage of 220 V and a mains frequency of 60 Hz, is designed for a rated power of 45 kW.