DAM DISCHARGES FOR GENERATION OF PEAK HYDRO ELECTRIC POWER

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ABSTRACT

The crisis in electricity power generation in South Africa is well known. It's not so much base load generation but the peak power consumption that's the problem. Thermal, solar and wind power generation are not suited to meet peak load power; hence the few pumped storage schemes in SA. However, there are numerous dams in Southern Africa requiring steady consumptive and environmental releases, which can be used to generate small scale hydro-electric power. This paper presents a case study of an application at the Maguga Dam hydro-electric station, Swaziland, with particular reference to automatic water control equipment to regulate downstream flow to meet environmental requirements. The paper presents advantages of developing peak power generation from dams in South Africa.

1. INTRODUCTION

South Africa is a semi arid country and is not blessed with large rivers which can be used to generate continuous hydro power such as the Zambezi, Kafue and Congo rivers in our northern SADC countries. It's only the Ash River in SA which enjoys the continuous large outflow from Katze Dam, and the lower reaches of the Orange River that have been selected for hydro power generations and then, the output capacity is still only limited to less than 25Mw. Hydropower therefore does not feature strongly in the Department of Energy's renewable programmes.

There are in the order of 1500 large dams in South Africa, all of which are designed to store and release water.

However, the releases are generally small, mostly in the order of 2m^3/sec or less and nearly all are continuous discharges for consumptive and environmental purposes.

If these continuous discharges are used to harness hydro electrical power, the electricity output would invariably be less than 500kw for a 40m high dam, which although helpful, is not significant.

The usefulness of this discharge can be greatly improved if peak power generation is harvested.

2. PEAK POWER GENERATION

It is the shortfall of power at the peak load periods that is the "Achilles heel" of South Africa' power supply. Thermal, solar and wind generated power cannot respond quickly enough to peak power loads. Only hydro and gas turbines can respond quickly to peak loads. Gas turbines are however hugely expensive to run.

The peak period is generally applied as 3 hrs in the morning between 6 to 9am and 3hrs in the early evening from 6 to 9pm, a total of 6 hours per day.

Offpeak is then the night period of 9 hrs from 9pm to 6am the next day and the day time period from 9am to 5pm is standard time.

Each of these periods has different tariffs for bulk users and because the tariffs increase annually, a dimensionless unit T^c /Kwhr, is used for offpeak period to demonstrate the effectiveness of peak power generation.

The ratio of tariffs is then:

- Offpeak 1 T /Kwhr
- Standard 2 T /Kwhr
- Peak 2,5 T /Kwhr

The ratios are based on actual ratios from a bulk electricity consumer but can vary depending on arrangements with ESKOM. They however give an indication of the considerably higher tariff applied to peak power.

In a typical example of a large majority of South African dams discharging 1,5m^3/sec at a head of 40m, the daily power generation would be 500kw or 12 Mwhrs / day. The income generated from this continuous discharge in then

Power Production		**Revenue**	**% Power Contribution**
• Offpeak 500kw x 9hrs x 1 T	=	5000 T	21,4
• Standard 500kw x 9hrs x 2 T	=	9000 T	42,8
• Peak 500kw x 6hrs x 2,5 T	=	7500 T	35,8
Total / day		21000 T	100,0

The total volume discharged per day is 24hrs x 1,5m^3/sec x 3600sec = 129 600m^3

However, if the same volume is discharged over 6 hrs, the discharge rate is 6 m^3/sec compared to 1,5m^3/s for continuous discharge.

The power output of the dam is then 2 Mw instead of 0,5 Mw and the revenue generated for peak power is 2000kw x 6hrs x 2,5 T = 30 000 T/day. This is a 43% increase on the revenue generated over the continuous discharge generating only 500 Kw.

If one accepts that the offpeak tariff is in the order of R 0, 5 /Kwhr. The annual income would be in the order of R 5, 5 million and the cost of installation of the hydro plant should be recovered in less than 4 years.

The other advantage of the increased installed capacity of 2 Mw for 6m^3/sec is that during periods of high flows when the dam is overflowing, the hydro power plant can generate 2 Mw for longer periods than 6hrs, even up to the entire day, thereby increasing revenue substantially.

The capital costs to fit a hydro power station to an existing dam is usually considerably lower than other sources of renewable energy because the major infrastructure, being the dam, roads etc, is already in place.

3. DOWNSTREAM FLOW REGULATION

The increased discharge from the dam to generate peak power may in some instances, cause safety and environmental concerns to the downstream river reach and downstream users.

The fourfold increase in average flow over a shorter period may cause increased scour to the river banks as well as a safety risk to people using the river.

Each downstream river reach would therefore need to be evaluated for risk. For smaller discharges there may be very little risk if there is very little development along the water course for some distance as the channel storage will attenuate the peak discharge, to give an almost constant flow over the day.

However, if normal continuous downstream is required, then a low regulating weir can be built downstream to store the peak power discharges and release it as a continuous flow over the day.

In the above example of 6m^3/sec peak discharge, the regulating weir would need to have a storage capacity of 50 000m^3. This might require only a 3 to 4m high masonry weir.

The constant discharge could be achieved by a series of orifice type pipe outlets positioned at different heights or an automatic regulating valve or gate. This was done at the Maguga Dam in Swaziland.

4. MAGUGA DAM REGULATING WEIR

The Maguga Dam is situated on the Komati River in Swaziland. It is joint venture between Swaziland and South Africa and is the main dam operated by the Komati Basin Water Authority (KOBWA).

The dam is 115m high, rock filled dam with a 19,5Mw capacity hydropower station at the dam outlet.

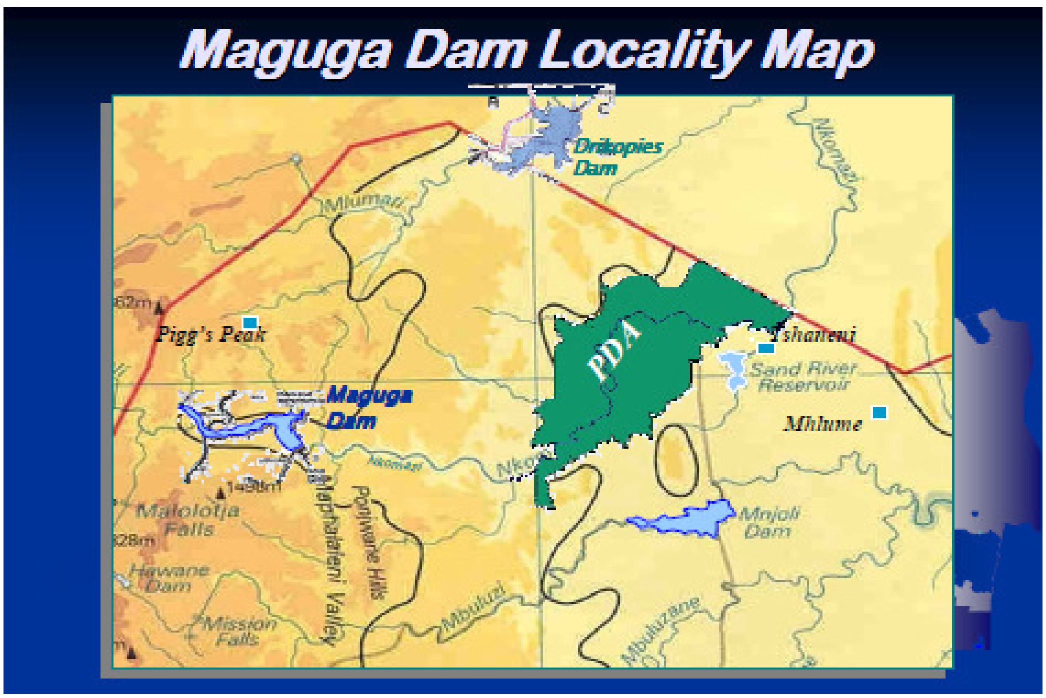

Figure 1 Maguga Dam Locality Map

The PowerStation generates peak power over 5hrs of the day. The peak power discharge is in the order of 25m^3/sec. For environmental and downstream user requirements, the peak discharges are regulated to a constant downstream flow at a regulating weir.

The regulating weir is a 25m high concrete structure situated 2,5km downstream of the power station. The water levels rise and fall behind the wall over a range of 4 to 6m depending on the power generated and water releases from the dam.

Figure 2 Maguga Dam, Swaziland

The regulating weir storage capacity is 1 million and the outflow into the downstream Komati River reach is controlled by two large automatic regulating valves, each with a maximum capacity of 12,5m^3/sec. The downstream flow rate is determined and called for by Royal Swaziland Sugar Corporation to meet their and other sugar estate extraction requirements. The outflows vary from 18m^3/sec down to about 6m^3/sec depending on the seasonal water requirements.

Photograph 1 Regulating weir with DV chamber and discharge channels in foreground

The outflow is measured over a crump weir in each chamber and the flow rate set by a float control valve at the crump weir. The automatic valves automatically, and without electrical input, regulate the outflow with the varying upstream head.

The valves are Fluid Dynamic System (FDS) Diaphragm valves (DVs), each 1,6m diameter operating under a maximum head of 12m. The valves were installed in 2006.

Photograph 2   1600NB Diaphragm Valve

The DVs are downward facing bends with a diaphragm controlled deflector pot. The pressure from the upstream water level is fed into the diaphragm and then continues to a float control valve at the crump weir.

If the water level at the crump weir rises above the required flow rate, the float valve closes down slightly to pressurize the diaphragm to close the DV slightly to reduce the outflow. If the flow rate is below the required level over the crump weir, the float valve opens to relieve pressure in the diaphragm and the DV opens slightly. The DV does not hunt but reached the required level over the crump weir and then maintains the constant discharge.

Photograph 3   Crump weir for flows up to 12,5m^3/sec

The float valve is operated by a hand wheel and spindle to set the float at the required flow for that day. The outflows can vary daily depending on downstream required.

The water discharges radially from the DV into a concrete chamber and dissipates the kinematic energy within the chamber. The flow then passes through a bank of flow straightener pipes into a stilling channel leading to the crump weir. This form of energy dissipation is very effective in reducing the length and extent of structure required to reduce the pressurized outflow to steady state conditions.

Photograph 4 DV discharging radially into chamber to dissipate energy

5. CONCLUSION

1. Peak power generation is considerably more important, with higher revenue generation capacity, than continuous power generation from smaller continuous discharges.

2. There is a considerably number of large dams in South Africa which can be utilized to generate peak power.

3. The aggregate amount of peak power that can be generated from a number of dams will have a meaningful impact in addressing our power crisis, which is the provision of peak power.

4. The peak flow rates can be regulated by a low weir, with either uncontrolled or controlled outlets.

5. The capital costs for hydropower stations attached to existing dam outlets is considerably lower than other forms of renewable energy and therefore more viable in terms of cost and time to commission.

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