Maximising hydro-power generation within a multi-user water supply system

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INTRODUCTION

In order to optimise the generation of hydro-power from Gariep and Vanderkloof dams, and to supply the other water users at the required risk levels, a system utilisation agreement was formed between the Department of Water Affairs (DWA) of the Republic of South Africa (RSA) and Eskom (the national energy supplier within the RSA). As part of the agreement between DWA and Eskom, DWA commissioned the Orange River System Annual Operating Analysis study to ensure that all the users are supplied at the required assurance and to determine the volume of water available for the generation of hydro power on an annual basis.

Background

Gariep and Vanderkloof dams are the two largest dams in the RSA, located in the Orange River, with gross storages of 5343 million m^3 and 3187 million m^3, respectively. Several water supply sub-systems, including the well known Lesotho Highlands Water Project (LHWP), are located upstream of Gariep and Vanderkloof dams. These sub-systems, some with large transfers, all have an effect on the water availability in Gariep and Vanderkloof dams, also referred to the as the Orange River Project (ORP). The total 2008 demand imposed on the ORP is in the order of 3200 million $m^3/year^{-1}$ and is just lower than the historic firm yield of 3 349 million $m^3/year^{-1}$.

Irrigation requirements represent 59% of the total demand, followed by 36% for river requirements and losses and 5% for urban industrial mining requirements. Most of the time hydro-power requirement is a non-consumptive demand as it is generated with water released to satisfy downstream requirements. In times when a short-term surplus does exist in the system, a discretional allocation is given to Eskom for additional hydro-power generation.

The demand for hydro-power is, in general, high in the winter and low in the summer, while an almost inverse pattern is required for irrigation purposes. Each of the different types of user in the system requires a certain assurance of supply, which is the lowest for irrigation and the highest for hydropower generation purposes. It therefore poses a challenge to operate the dams in such a manner as to be able to adhere to the conflicting demand requirements between the different users, and to be able to generate as much hydro-power as possible without jeopardizing the assurance of supply to all the users. The system is currently almost fully utilized and allows very little room to correct any mis-management.

The overall electricity supply in the RSA is currently under severe pressure due to lack of generating capacity. With the World Cup soccer taking place during the 2010 winter period, high energy demands are expected, which places a high demand on the hydro-power plants at Gariep and Vanderkloof dams.

Operating rules developed for the ORP sub-system

A comprehensive set of operating rules were developed for the ORP as far back as 1995. At the time when these operating rules were developed, decisions with regard to the annual water allocation and possible restrictions in water use were made once a year based on the storage in the dams on 1 May, which is the time of year when most of the summer rainfall–runoff has entered the dams.

Further refinements and adjustments to the operating rule were required as a result of changed Eskom requirements, as well as the fact that the system is currently almost 100% utilised, and improved operation procedures are therefore required.

The RSA rivers are, in general, well known for the high variability in flow, and with relative short flow records in most places, it is difficult to properly determine the assurance of supply from these river systems. Highly sophisticated models and modelling techniques were developed in the RSA by DWA to successfully overcome this problem. These modelling tools and techniques are also utilised for the ORP and involve the use of the Water Resources Yield and Water Resources Planning Models. For this modelling purpose, up to a 1000 stochastically-generated flow sequences, based on the historic naturalised observed flow record, are analysed to determine the system behaviour and enable the user to determine the yield or supply at low and very high assurances, up to 1 in 200-year (99.5%) assurances. Short-term stochastic yield characteristics were determined for the ORP system. These short-term yields are very dependent on the starting storages in the dams and are therefore used as part of the operating rule to ensure that all the users are supplied at their required assurances and to be able to impose curtailments on the system to avoid total system failure, which will have catastrophic results.

Several other components were also built into the operating rule and typically include the following:

– Allocation curve (allocation of surplus water in the system to Eskom).
– Mirror pattern for releases from Gariep Dam to increase hydro-power generation in the winter.
– Release rule for releases from Gariep Dam to protect users that can only utilise Gariep Dam as source.
– Flood control curve when dams are full or close to full supply level to reduce spills and increase hydro-power generation.
– Vanderkloof Dam operating level to minimise zero hydro-power generation occurrences at Vanderkloof Dam during extreme droughts.
– Energy demand pattern to ensure that generated power is in line with the energy demand pattern through the year.
– Further improvements and refinements were recently made to the operating rules as well as additional measures to assist Eskom during the World cup soccer in 2010 to ensure a stable energy supply during this period. Details of these will be provided in the full paper.

CONCLUSIONS

The ORP system was successfully managed and operated over the last approximately 15 years using these models and modelling techniques. During this period the demands imposed on the system have increased significantly and large developments such as the LHWP took place upstream of the ORP, having significant effects on the water supply from the ORP.

The further refined and improved operating rules have already proved to increase power generation, reduce spillage from the dams and still been able to supply to the users at their required assurances.

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