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Optimization in Operating for Linking Reservoirs at Sesan Cascade in the Highland Of Vietnam

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Abstract

Differential Evolution and Dynamic Programming are used in reservoir regulation in many research. In the previous works, we presented the outline of Differential Evolution and Dynamic Programming and separately applied them into Pleikrong reservoir and Ialy reservoir, two biggest ones in the Highland of Vietnam for dry season of 2010 and 2012. Continuing from that, in this work, we apply these methods to these two reservoirs at the same time as a multi-reservoir system to reach optimal regulation for the maximum power production.
Keywords: DP, DE, Reservoirs, Optimization, Pleikrong Reservoir, Ialy Reservoir.

1 Introduction

Nowadays, the demand for electricity is increasing. Hydro-electricity plays an important role in the electricity system of Vietnam. However, the amount of water is decreasing. The problem of for Vietnam and many other countries in the world is how to use the water effectively to meet the demand of electricity but still stay friendly to the environment.

In hydro-power, dams are built and water is kept in the reservoirs then it would be used for several purposes at the same time such as: flood prevention, power generation, irrigation, water transport, and water supply for downstream (Nguyen Tien Cuong, 2008), (H. Van Lai, 2009). However, these tasks often conflict to each other. For example: in the rainy season, the amount of water is high, it is necessary to prevent flooding but too much water can break down the dams; in the dry season, downstream needs more water for irrigation but it is also need to keep water for the output of the

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power stations. That is why the power stations need to be operated optimally and reservoir optimization problem is a significant practice problem in the world and Vietnam in particular.

Depending on specific project characteristics and the amount of incoming water, each reservoir has a priority target that follows specific standards and constraints. Therefore, the optimal problem statement for different reservoir is different, there cannot be a general formula for all.

Multi-reservoir regulation problem has been implemented in many parts of the world (Nadalal, 1995). In Vietnam, there are few research about this problem (N. The Hung, 2011), (Hung, 2012). The optimal problem for reservoirs in Sesan cascade was also study to optimize the electricity by linear programming (Tien, 2006). In this report, we would like to introduce the problem of regulating hydropower reservoirs in case of linking two biggest reservoirs of Sesan cascade: Pleikrong and Ialy, by Dynamic Programming and Differential Evolution - a genetic algorithm. The total output of the two reservoirs is calculated with three different scenarios and the results are compared.

2 Subjects, Problems and Methods

2.1 Subjects

There are several hydropower plants which are linking together in Sesan cascade: Pleikrong, Ialy, Sesan 3, Sesan 3A, Sesan 4. As we can see, these reservoirs are closely linked to each other. The outputs (releases) of this reservoir are the inputs of the next one. Pleikrong is the first one in the ladder of the reservoirs. It comes from Prong Poko river. Ialy is the second one and has two inflows: from Dak Bla river and from the outputs (releases) of Pleifrong reservoir. Pleikrong and Ialy, which are two biggest constructions in this reservoir ladder, are the subjects of this study.

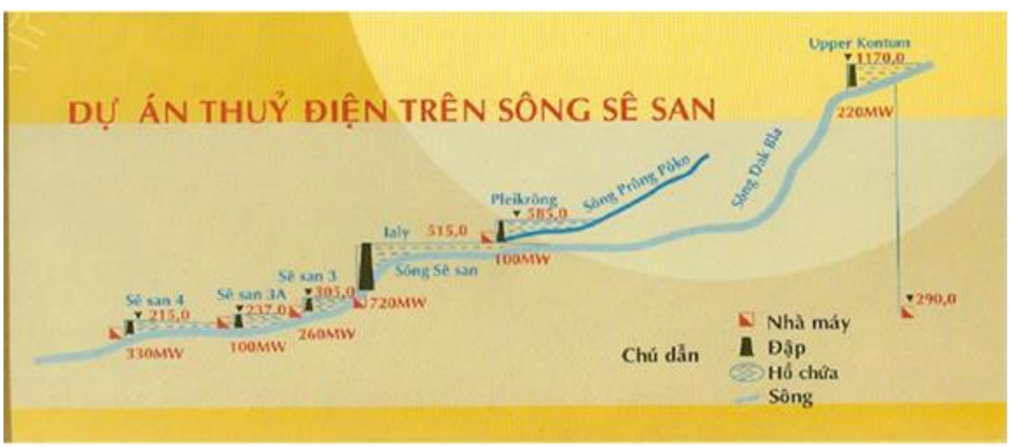

Figure 1: Diagram of hydropower plants in Sesan cascade (Ialy, 2003)

Figure 1: Diagram of hydropower plants in Sesan cascade (Ialy, 2003) shows the position, also the wattages and the normal water levels of the reservoirs (or power plants) in the ladder.

The hydropower system can be described as in Figure 2: Diagram of calculating scope below:

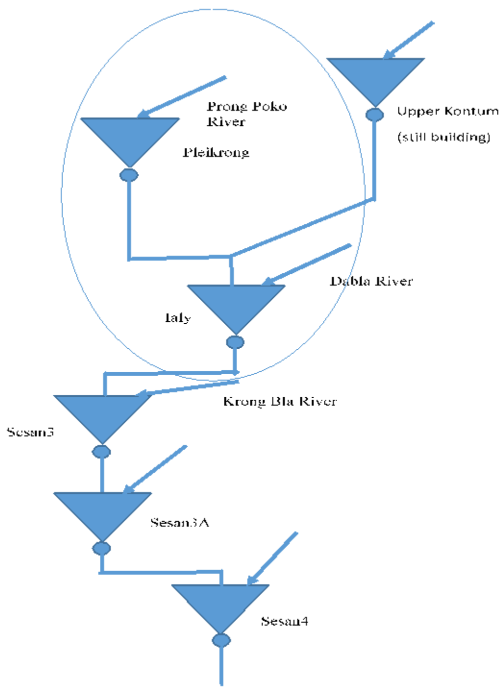

Figure 2: Diagram of calculating scope

In this study, we are concerned about two biggest reservoirs in the ladder which are Pleikrong and Ialy. These two reservoirs have the main role in the electricity system of the area.

2.2 Problem

The problem in this study is set as bellow:

Finding the optimal set of releases to get the maximum of total electricity production from both reservoirs Pleikrong and Ialy in dry season of 2010. The calculating time is 140 days that we separate into 14 periods, each period is 10 days (followed by The decision in operation rules for reservoirs in Sesan cascade, No. 1182 QD-TTg of the Government of Vietnam signed in July 17, 2014) (The decision in operation rules for reservoirs in Sesan Cascade, No. 1182 QD-TTg of the Government of Vietnam , 2014)

The objective function in this case is:

$$E = \text{Maximum } \Sigma \text{ Ej} \qquad (j= 1,..., T) \tag{1}$$

Where:

$$E_i = 9.8 * h_i * Q_i * k * 24 * 10/1000 \,(MWh) \tag{2}$$

Ei - electricity of period i

hi - water height at time period i,

qi - release at time period i,

k – overall generation efficiency

Using inputs that are already given in 2010, we set 3 scenarios:

Pleikrong reservoir is using real operation, only optimize the operation of Ialy reservoir.

Optimize the operation of Pleikrong reservoir only, Ialy reservoir is real operated

Optimize both reservoirs at the same time

Then we compare the total electricity power of two reservoirs to find out which scenario gives the highest amount of electricity power.

2.3 Methods

We use two methods to solve this problem:

2.3.1 Dynamic Programming

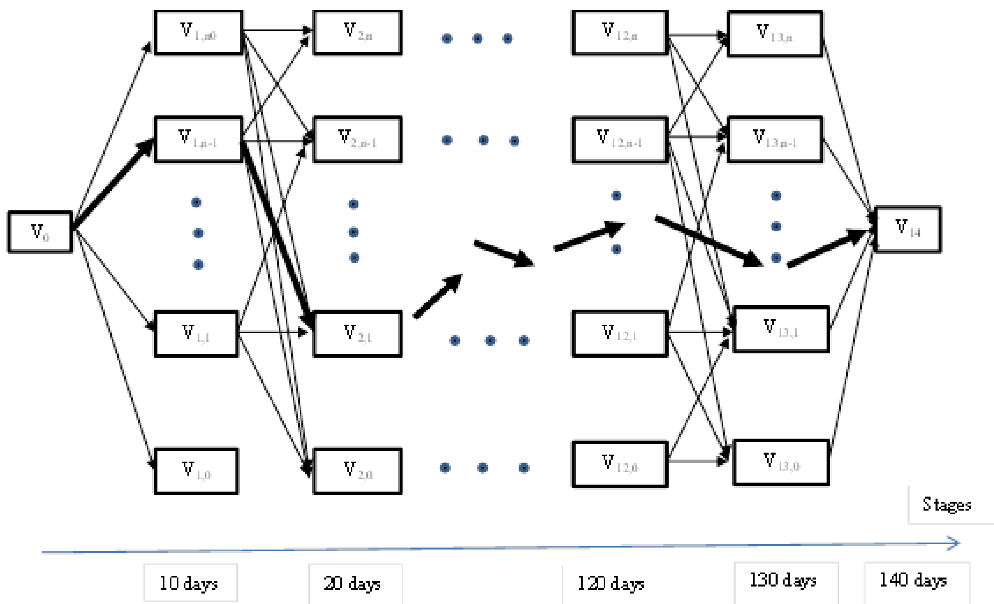

Figure 3: Chart of Dynamic programming (Phuong P.T.T H. D., 2017)

There are 14 periods now called 14 stages.

The maximum electricity power of all 14 stages is the sum of the electricity from each stage by the optimal way.

From the initial volume, we calculate all possible options of releases that satisfy the structure design and the inputs, then calculate the electricity corresponding to them. The releases give the highest electricity is the optimal set of releases to operate in the stage.

In the next stages, the initial volume is the volume of the reservoir after the previous stage and the inflow from the upper stream.

2.3.2 Differential Evolution

Differential Evolution is a branch of Genetic algorithm.

In this method, we use the real operation as the initial solution:

$$x_0 = \left(x_{01}, x_{02}, \ldots, x_{0n}\right)^T \quad n = 14 \tag{3}$$

Then we create the solution of the next step by adding a weighted differences between the given solutions to each value of the solution

$$V_i^{(G+1)} = X_{r1}^{(G)} + F\left[X_{r2}^{(G)} - X_{r3}^{(G)}\right] \tag{4}$$

F > 0 is a real random parameter, called mutant constant, which controls the difference between two individuals, used to avoid the slow searching.

This step is called mutant

r1, r2, r3 are random integers chosen from 1 to NP.

After the mutant step, we calculate the electricity by new solution. If the electricity by the new solution is higher than the previous one then it is kept for the next step.

The loop will be repeated until the optimization of the problem has been reached.

2.3.3 Inputs

The data that is used in this paper was provided by the team of Institute of Mechanics of VAST in project of building the reservoir operation for Sesan cascade in dry season (process of multi-reservoir operation on the Sesan river basin of the Prime Minister, 2014).

In Table 1: Input of Pleikrong reservoir and Ialy reservoir in 2010 and 2012 and Table **2**: Inflow of Pleikrong reservoir and to Ialy reservoir from DakBla river in the year 2010, the design parameters of Pleikrong and Ialy power plants are given. These parameters are used as the inputs and the constraints of the problem.

	Plei2010	**Ialy 2010**
Total volume (x10^6 m^3)	1.048,691300	1037000000
Useful volume (x10^6 m^3)	948,430000	779,000000
Normal water level (m)	570	512
Turbine water level (m)	514	304
Death storage (x10^6 m^3)	100,261300	263,830000
Death water level (m)	537,000000	490,000000
Initial volume (x10^6 m^3)	1.096,894100	396,939548
Initial storage (x10^6 m^3)	996,632800	660,769548
Initial water level (m)	569,000000	506,590000
Maximum release (m^3/s)	330,000000	420,000000
Overall generation efficiency	0,898869	0,900125

Table 1: Input of Pleikrong reservoir and Ialy reservoir in 2010 and 2012

N0 period	Time of period	Inflow to Pleikrong reservoir (m^3/s) in 2010	Inflow to Ialy reservoir from DakBla river 2010
1	11/Feb-20/Feb	47.73	52.43
2	21/Feb-02/Mar	53.35	41.9
3	03/Mar-12/Mar	23.79	49.63
4	13/Mar-22/Mar	51.8	37.25

5	23/Mar-01/Apr	31.98	26.98
6	02/Apr-11/Apr	10.86	41.55
7	12/Apr-21/Apr	44.56	46.58
8	22/Apr-01/May	41.18	46.2
9	02/May-11/May	14.54	60.05
10	12/May-21/May	23.54	42.28
11	22/May-31/May	0.09	43.08
12	01/Jun-10/Jun	17.15	56.55
13	11/Jun-20/Jun	44.76	41.25
14	21/Jun-30/Jun	36.48	43.43

Table 2: Inflow of Pleikrong reservoir and to Ialy reservoir from DakBla river in the year 2010

3 Results And Discussion

3.1 Results

We calculate the total electrical production of two reservoirs in 2010 in three scenerios:

1. Pleikrong is using real operation, only optimize the operation of Ialy.
2. Optimize the operation of Pleikrong reservoir only, Ialy reservoir is real operated.
3. Optimize both reservoirs at the same time.

The solutions of scenario 1, which is optimize the operation of Ialy reservoir by two methods, are shown in the Table 3: Optimal releases of Ialy reservoir by DP and DE in 2010 in scenario 1 (Using real operation of Pleikong)

The solutions of scenario 2, which is optimize the operation of Pleikrong reservoir using Dynamic Program and Differential Evolution, are shown in the Table 4: Optimal releases of Pleikrong reservoir by DP and DE in 2010 in scenario 2 (using real operation of Ialy)

Table 5: Optimal releases of two reservoir Pleikrong and Ialy at the same time by in 2010 in scenario shows the solutions of scenario 3, which is optimize both reservoirs at the same time.

N0 period	Time of period	Optimal releases of Ialy reservoir by DP (m^3/s)	Optimal releases of Ialy reservoir by DE (m^3/s)
1	11/Feb-20/Feb	8.386377	0
2	21/Feb-02/Mar	0.384566	0
3	03/Mar-12/Mar	58.12228	72.479129904
4	13/Mar-22/Mar	126.35	101.31
5	23/Mar-01/Apr	189.48	188.70
6	02/Apr-11/Apr	248.25	236.27

7	12/Apr-21/Apr	215.98	223.31
8	22/Apr-01/May	169.2	165.54
9	02/May-11/May	223.25	238.79
10	12/May-21/May	188.08	134.46
11	22/May-31/May	124.88	118.99
12	01/Jun-10/Jun	179.3757	163.57164806
13	11/Jun-20/Jun	418.9286	420
14	21/Jun-30/Jun	410.7174	420
	Electrical production	**1, 107,901.55 MWh**	**1,081,234.99 MWh**
	Real electrical production	**1,063,948 MWh**	

Table 3: Optimal releases of Ialy reservoir by DP and DE in 2010 in scenario 1 (Using real operation of Pleikong)

N0 period	Time of period	Optimal releases of Pleikrong reservoir by DP (m^3/s)	Optimal releases of Pleikrong reservoir by DE (m^3/s)
1	11/Feb-20/Feb	2.540329861	0.0
2	21/Feb-02/Mar	38.28677662	40.53416590
3	03/Mar-12/Mar	23.79	23.78999995
4	13/Mar-22/Mar	51.8	51.80000037
5	23/Mar-01/Apr	31.98	31.98000024
6	02/Apr-11/Apr	10.86	10.86000043
7	12/Apr-21/Apr	44.56	44.56000130
8	22/Apr-01/May	41.18	41.17999976
9	02/May-11/May	14.54	14.53999904
10	12/May-21/May	23.54	83.22103829
11	22/May-31/May	228.1684399	199.33007812
12	01/Jun-10/Jun	322.287357	277.37941453
13	11/Jun-20/Jun	319.3836213	329.80134326
14	21/Jun-30/Jun	326.3604892	329.97833269

	Electrical production	**141,060.59 MWh**	**141,079.08 MWh**
	Real electrical production	**133,547 MWh**	

Table 4: Optimal releases of Pleikrong reservoir by DP and DE in 2010 in scenario 2 (using real operation of Ialy)

N0 period	Time of period	Optimal releases of Pleikrong reservoir (m^3/s)	Optimal releases of Ialy reservoir (m^3/s)
1	11/Feb-20/Feb	62.6	0
2	21/Feb-02/Mar	84.1	19.4
3	03/Mar-12/Mar	0	63.2
4	13/Mar-22/Mar	106	137
5	23/Mar-01/Apr	72.5	37.5
6	02/Apr-11/Apr	212	241
7	12/Apr-21/Apr	0	53.9
8	22/Apr-01/May	122	163
9	02/May-11/May	284	360
10	12/May-21/May	226	215
11	22/May-31/May	188	225
12	01/Jun-10/Jun	41.1	171
13	11/Jun-20/Jun	44.8	382
14	21/Jun-30/Jun	36.5	420
	Electrical production	**188,503.63 MWh**	**1,072,544.71 MWh**

Table 5: Optimal releases of two reservoir Pleikrong and Ialy at the same time by in 2010 in scenario

We have the total electrical production of two reservoirs in 2010 in three scenarios shown in Table 6: Electricity production of two reservoirs in 2010 by 3 scenarios and in chart forms as Figure 4: Total electricity of Pleikrong and Ialy in 2010 as following:

Scenerio	Electricity production of Pleikrong	Electricity production of Ialy	Sum
Real operation	133,547 MWh	1,063,948 MWh	**1,197,495 MWh**
1	133,547 MWh	1,081,234.99 MWh	**1,214,781.99 MWh**

2	141,079.0869 MWh	1,063,948 MWh	**1,205,063.09 MWh**
3	188,503.63 MWh	1,072,544.71 MWh	**1,261,048.34 MWh**

Table 6: Electricity production of two reservoirs in 2010 by 3 scenarios

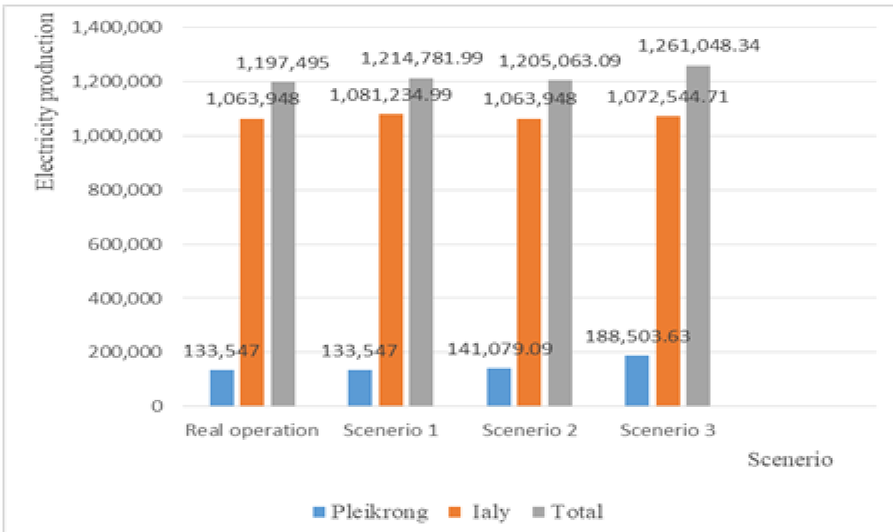

Figure 4: Total electricity of Pleikrong and Ialy in 2010

3.2 Discussion

As we can see in Table 3: Optimal releases of Ialy reservoir by DP and DE in 2010 in scenario 1 (Using real operation of Pleikong), Table 4: Optimal releases of Pleikrong reservoir by DP and DE in 2010 in scenario 2 (using real operation of Ialy) and Table 5: Optimal releases of two reservoir Pleikrong and Ialy at the same time by in 2010 in scenario, the trend of operation to reach maximum power electricity is storing the water at the beginning then giving massive discharges at the end of the calculation time.

From Table 6: Electricity production of two reservoirs in 2010 by 3 scenarios and Figure 4: Total electricity of Pleikrong and Ialy in 2010, the total electricity from Ialy reservoir in 2010 is nearly ten times bigger than Pleikrong reservoir and optimizing both reservoir at the same time gives the highest electricity production in three scenarios.

4 Conclusions

The present study shows that water releases are depended on the inflows to the reservoirs. To reach the maximum electricity production, it needs to keep the water then increases the releases at the end of the season. In three scenarios, the main electricity of these two reservoirs is from Ialy. It is nearly 10 times of the electricity from Pleikrong reservoir. The scenario which optimizes both reservoirs at the same time give the highest amount of electricity production.

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