# Planning for the utilization of hydro power in the Belayan river, East Kalimantan

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**Abstract.** Non-renewable energy power plants are barely able to meet all electricity needs but they have negative impacts on the environment as does greenhouse gas pollution. For now, investors and academics are competing to make renewable energy power plants, one of them is hydroelectric power plant. National Energy General Plan Data (RUEN) issued by the government shows that East, Central and South Kalimantan has water potential in the amount of 16.844 MW. Therefore, this study chose Tabang, East Kalimantan as a case study to build a hydroelectric power plant. Belayan River according to the East Kalimantan Region III River Agency has potential water reaches 424,36 $m^3/s$, so it is very strategic for hydroelectric power plants. The survey results provide 3 possible alternatives for dam construction. The type of water turbine chosen is Francis vertical shaft with output power 71.701,98 kW and generator with output power 69.550,922 kW. The output power that can be generated by this hydroelectric power plant is equal to 280 MW by use 4 generating units.

## 1. Introduction

Alternative energy or commonly referred to as a solution to all the problems of the energy crisis that exists in the world provides several options, namely, hydropower, solar energy or solar power plants and wind power plants [1]. Each alternative energy choice certainly has a different impact, depending on location, resources produced, impacts on the surrounding environment, and others [2].

Indonesia is an island nation that has the potential of each type of alternative energy. However, based on the results of previous studies, it would be more efficient in Indonesia to apply alternative energy based on water flow, namely hydropower, for renewable energy programs [3]. East Kalimantan is a province that has water energy potential because it is supported by a large number of river channels with a large amount of discharge. One area that is very suitable for building hydropower is Tabang, in Kutai Kertanegara Regency.

National Energy General Plan (RUEN) data released by the government shows that East, Central and South Kalimantan have a water potential of 16,844 MW. This potential is, of course, a power plant that can meet electricity needs in East Kalimantan because the National Capital will be moved to East Kalimantan. The move of the State Capital will make high electricity demand in East Kalimantan. So

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that it is expected that the construction of a hydroelectric power plant in Tabang can help meet electricity needs in the future [4].

However, the figure is also questioned whether this potential can be realized or not. In this study, we will analyze the planning and utilization of water in East Kalimantan as a hydroelectric power station, thus, it can be seen the potential of the Belayan River as a hydroelectric power station.

## 2. Methods

### *2.1. Research sites*

Tabang is one of the sub-districts in the interior of Kutai Kartanegara Regency which is located in an intermediate position 115° 26' BT – 116° 18' BT and 1° 28' LU – 0° 18' LU. Basic data on the potential of the Belayan river to be used as hydropower can be obtained through preliminary studies, surveys and data analysis[5]. The survey was divided into several aspects including implementation, aspects of hydrological conditions, rainfall, water availability, and regional geology. Figure 1 is the Location of the Tabang Hydroelectric Power Plant from Tenggarong City[6]. Table 1 is the discharge generation data for the Belayan River in 1990-2008 from the East Kalimantan River Region III Agency.


**Figure 1.** Location of Tabang hydroelectric power plant from Tenggarong city

**Table 1.** Belayan river discharge generation data for 1990-2008

| Year | Jan | Feb | Mar | Apr | Mei | Jun | Jul | Aug | Sep | Okt | Nov | Dec | Annual Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 230,87 | 152,21 | 342,94 | 314,86 | 132,82 | 214,1 | 332,62 | 367,48 | 301,95 | 153,64 | 473,97 | 590,56 | 300,67 |
| 1991 | 459,21 | 545,11 | 425,95 | 893,62 | 580,91 | 385,59 | 401,32 | 329,27 | 403,08 | 313,75 | 531,78 | 497,63 | 480,60 |
| 1992 | 504,58 | 543,39 | 291,06 | 263,22 | 404,75 | 230,54 | 267,75 | 142,07 | 117,44 | 194,02 | 333,07 | 312,97 | 300,41 |
| 1993 | 143,42 | 261,60 | 450,93 | 260,57 | 222,42 | 223,35 | 201,89 | 112,01 | 189,50 | 350,26 | 184 | 265,87 | 238,82 |
| 1994 | 241,29 | 230,58 | 238,3 | 224,98 | 279,97 | 269,91 | 121,16 | 96,93 | 88,92 | 143,39 | 67,80 | 235,15 | 186,53 |
| 1995 | 109,13 | 102,3 | 250,8 | 158,54 | 140,66 | 202,92 | 123 | 147,62 | 74,72 | 100,42 | 237,97 | 133,34 | 148,46 |
| 1996 | 302,12 | 264,88 | 105,71 | 178,45 | 161,21 | 186,67 | 200,61 | 88,37 | 81,73 | 288,82 | 627,21 | 544,24 | 252,5 |
| 1997 | 510,46 | 468 | 468,31 | 485,09 | 374,91 | 328,98 | 184,88 | 600,43 | 526 | 410,75 | 428,27 | 477,94 | 438,65 |
| 1998 | 282,5 | 204,13 | 147,5 | 143,9 | 296,27 | 496,55 | 675,27 | 251,06 | 318,08 | 498,09 | 649,25 | 815,7 | 398,19 |
| 1999 | 830,65 | 826,97 | 735,26 | 647,51 | 631,56 | 551,16 | 433,29 | 352,75 | 461,73 | 332,56 | 702,5 | 584,85 | 590,9 |
| 2000 | 515,38 | 542,95 | 530,32 | 629,98 | 663,87 | 544,05 | 494,05 | 554,12 | 350,04 | 423,66 | 790,45 | 445,25 | 540,76 |
| 2001 | 885,28 | 1503,17 | 1477,55 | 1455,2 | 1288,41 | 777,6 | 512,25 | 877,13 | 516,99 | 526,45 | 394,12 | 1122,17 | 944,69 |
| 2002 | 662,13 | 668,09 | 577,93 | 687,59 | 736,78 | 563,91 | 303,1 | 242,17 | 200,2 | 178,53 | 526,8 | 319,01 | 472,19 |
| 2003 | 467,1 | 390,61 | 414,02 | 289,6 | 270,67 | 236,78 | 156,95 | 201,36 | 224,03 | 266,69 | 262,36 | 279,96 | 288,34 |
| 2004 | 365,17 | 319,88 | 141,71 | 211,83 | 187,82 | 196,15 | 265,05 | 108,71 | 137,53 | 78,09 | 267,55 | 463,38 | 228,57 |
| 2005 | 319,2 | 320,93 | 281,43 | 426,09 | 412,42 | 423,96 | 274,18 | 280,09 | 234,99 | 526,6 | 540,46 | 635,44 | 389,65 |
| 2006 | 1459,41 | 700,15 | 375,41 | 472,46 | 630,64 | 293,03 | 226,28 | 183,27 | 174,01 | 120,39 | 99,83 | 438,82 | 431,14 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 463,5 | 218,45 | 512,82 | 374,39 | 637,98 | 598,96 | 397,6 | 225,18 | 475,69 | 316,73 | 505,69 | 413,33 | 428,36 |
| 2008 | 370,51 | 455,1 | 490 | 788,89 | 698,36 | 490,14 | 512,11 | 453,74 | 346,84 | 414,29 | 750,88 | 663,65 | 536,21 |
| Max | 1459,41 | 1503,17 | 1477,55 | 1455,2 | 1288,41 | 777,6 | 675,27 | 877,13 | 526 | 526,6 | 795,45 | 1122,017 | 1503,17 |
| Average | 484,56 | 458,87 | 434,63 | 468,77 | 460,66 | 379,7 | 320,18 | 295,46 | 274,92 | 296,69 | 440,99 | 486,28 | 400,143 |
| Q(80%) | 266,02 | 255,73 | 245,8 | 219,72 | 208,59 | 219,65 | 194,32 | 130,04 | 129,49 | 149,54 | 252,60 | 299,77 | 153,35 |
| Q(90%) | 213,38 | 193,75 | 146,34 | 174,47 | 157,1 | 201,57 | 150,16 | 106,35 | 87,48 | 116,4 | 167,17 | 259,72 | 123,98 |
| Min | 109,13 | 102,38 | 105,71 | 143,59 | 132,82 | 186,67 | 121,16 | 88,37 | 74,72 | 78,09 | 67,8 | 133,34 | 67,8 |

| Persent (%) | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Discharge ($m^3/s$) | 1503,17 | 670,24 | 544,16 | 490,13 | 424,36 | 348,44 | 289,45 | 241,38 | 200,35 | 141,96 | 67,8 |

### *2.2. Research variable*

The research variables were obtained from the analysis of the planning of hydroelectric power plants using the Belayan River to determine the potential of the Belayan River. The calculation of generator planning analysis consists of net fall height, installed unit and generating output power.

This research uses primary data and secondary data. Primary data is data that is directly obtained from the results of measurements and observations at the research location, while secondary data comes from literature studies in the form of data that support analysis related to research[7]. Data analysis techniques using the concept of generator planning which is an optimal plant design plan with various limitations associated with technicians. The limitations of the problem stem from detailed field observations by determining the best engineering design and in accordance with the conditions at the Tabang Hydroelectric Power Plant site[8].

## 3. Result and discussion

Results and discussion in the form of dam location survey, dam design, water turbine type selection, generator and transformer selection.

### *3.1. Dam location survey*

The choice of alternative dam locations considers the width of the river, the shape of the river basin upstream of the dam, and the shape of the ridge next to the dam. Based on field studies, alternative dams I, II, and III were found at the foot of the dam. Geological conditions in the Tabang area have the appropriate characteristics to apply the type of dam containing rocks with upright nuclei (Zonal type)[9]. Figure 2 shows the alternative dams surveyed.


**Figure 2.** Alternative locations for tabang hydroelectric dam

The formulation of the project scale plan is carried out with an optimization study to obtain the optimal scale of the development of the Tabang Hydroelectric Power Plant at the dam site as an alternative, namely alternatives I, II, and III[10]. Optimization is carried out with various dam heights and reservoir volumes to regulate reservoir disposal which is used to produce electricity efficiently and economically. Some factors considered in determining the formulation of the plan include effective storage volume, company discharge, dam height, installed capacity, and energy production. Alternative locations of alternative dams I, II, and III can be seen more clearly in Figure 3, Figure 4, and Figure 5.

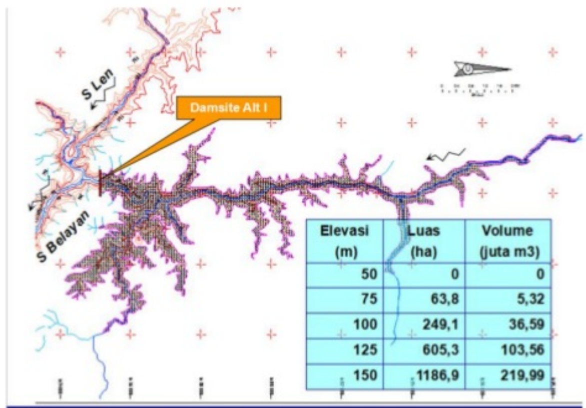


**Figure 3.** Alternative Dam Site I

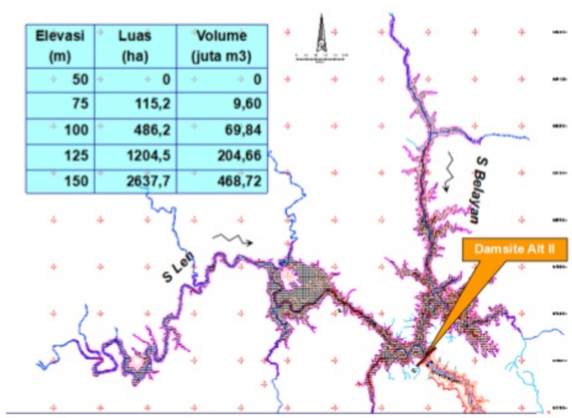


**Figure 4.** Alternative Dam Site II

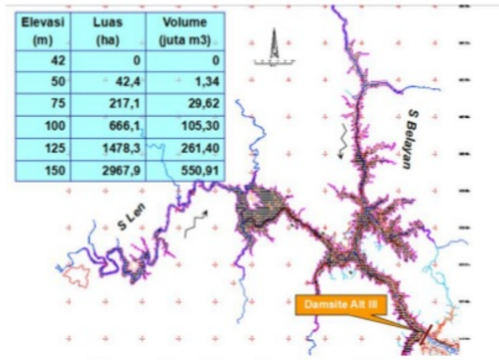


**Figure 5.** Alternative Dam Site III

From the calculation of height, area, and volume, alternative II was chosen as the location of manufacture for hydroelectric power plants in Tabang where one of the factors influencing the selection of alternative II was the ease of layout of the dam, its complementary buildings, and the volume of water in the dam watershed not far different from alternative III[11].

### 3.2. *Dam design*

The design of alternative dam II is close to the incorporation of water flow from the Len River[12]. Figure 6 is the design of the dam and other power plant components that are in accordance with the geographical conditions of Tabang.


**Figure 6.** Design of alternative dam hydro power plants II

The optimal dam design is carried out with various dam heights and reservoir volumes to regulate the discharge from the reservoir which is used to generate electricity efficiently and economically. Some factors that are considered in determining the formulation of the plan are the effective storage volume, firm discharge, dam height, installed capacity, and energy production. Table 2 is the optimal and efficient dam design.

**Table 2.** Dam optimization results data

| Variable | Variabel Value |
|---|---|
| Dam Height | 105 m |
| Dam Peak Elevation | El. 155 m |
| Full Supply Level | El. 149 m |
| Minimum Operate Level | El. 102,6 m |
| Tail Water Level | El. 52,95 m |
| Effective Reservoir Volume | 2508,48 $m^3$ |

| | |
|---|---|
| Rated Water Level | El. 142,12 m |
| Maximum Plant Discharge | 424,36 $m^3/s$ |
| Net Fall Height | 76,55 m |
| Sediment elevation | EL. 83,14 m |

### *3.3. Selection of water turbine type*
By using the data capacity on the dam and technical calculations, it is obtained that the net fall height is 76.55 m with water discharge per unit is 106.09 $m^3$/ s because it uses 4 units for plant reliability[13]. The maximum efficiency of a Francis turbine is 0.9, so the output power of the Francis type turbine with vertical shaft is 71.701,98 kW; thus, 4 turbines are needed to get a 286 MW power plant. Figure 7 is a graph of the choice of turbine type used to select the right turbine based on net fall height and water discharge.

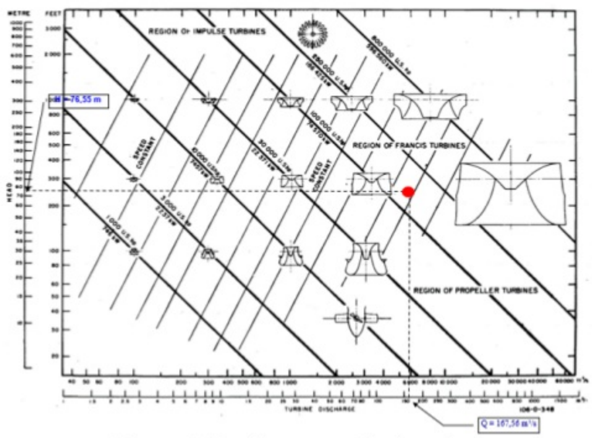


**Figure 7.** Turbine type selection chart

### 3.4. *Selection of generators and transformers*
By using high data the net fall is 76.55 m and the water discharge per unit is 106.09 $m^3$ / s. The efficiency of the generator produced from water turbines is 97%[14], then the output power of the generator is 69.550,922 kW and be rounded to 70 kW; thus 4 generators produce 280.000 kW of power. The transformer used uses a larger capacity than the generator capacity. Generator with a power factor of 0.85 produces a capacity of 85.000 kVA so the transformer used is 100.000 kVA[15]. In figure 8, it is a 100 MVA transformer

**Figure 8.** Transformer 100 MVA

## 4. Conclusion
From the research that has been done, it can be concluded that the construction of a hydropower plant in Tabang, Kutai Kertanegara Regency produces energy up to 280 MW by using 4 generator units.

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