reference 2: Explanation of Loss and Load Factor Issued by Design Institute

关于南令河一级电站有效电量，线损和厂用电率和年运行小时数的说明

1，有效电量

南令河一级电站位于云南省临沧市沧源佤族自治县，电站采用低坝取水，引水式径流式电站、不形成水库。电站总装机容量 8MW。

根据多年取水枢纽的水文统计资料，采用丰、中、枯三个代表年的来水量，再乘以自然水头、水轮机效率、发电机效率计算出来的三年平均值作为水电站的理论年发电量。但实际发电量和理论发电量有所区别，原因是实际发电量还受以下的变化因素影响：

（1） 当年来水水量和稳定性；

（2） 电站本身的性能，包括是否是多年、年、季、周、日调节能力，有调节性能的（一般是有水库的电站）比无调节的径流式水电站，系统更倾向接收和调度。

（3） 电网的情况，包括电网的容量限制，电网的维护及调度管理水平；系统负荷的变化；限电时段的长短等。

（4） 电站的管理水平：包括机电设备的维护水平及先进性；水工建筑的安全程度；操作人员的技术水平和负责程度；机组检修的时间；事故率的高低等；

（5） 自然环境的影响，包括控制集水面积内植被保护的情况，上游有无其他调节水库的兴建，上游人类活动的情况等。

以上情况有的可以控制，比如环境保护，电站自身的管理水平提高等。有的电站本身则难于控制或无法调节，例如所接电网的容量，电站本身的性能，系统限电时间等。实践证明多数小水电难以达到设计理论发电量。尤其是在水电比重大的电网或地区，例如云南省水资源较为丰富，水电站较多。这些电站由于受火电技术最小出力的限制，丰水期可作基荷运行的水电站被迫弃水调峰，形成日负荷低谷时发生弃水的情况。使得实际发电量远远达不到设计发电量。

为了对实际电量做合理的估计，我国《小水电建设项目经济评价规程》（SL16-95）第 3.2 条提出了一个“有效电量”的概念。即考虑到以上所列的多种因素水电站的实际发电量小于设计理论发电量的，如果按理论电量来进行经济评价，完全不考虑这些因素是不符合实际情况的。

对于小水电来讲，特别是无调节能力的小水电在系统中不可能承担负峰荷，只能在电网中根据系统的年内需要下达一定的计划，按计划运行，则难免产生弃水受限的情况，也不大可能参与系统的电力电量平衡基荷，因此要想通过电力电量平衡计算出来小水电实际年发电量是非常困难的。

《小水电建设项目经济评价规程》（SL16-95）第 3.4 条允许采用简化方法估算有效电量：

有效电量=设计发电量×有效电量系数，有效电量系数按《规程》3.4 表选用。

表 3.4 有效电量系数表

电站类别	有效电量系数 a
1、年或多年调节的联网电站	0.95~1.00
2、季调节的联网电站	0.90~0.95
3、月、周、日调节及无调节的联网电站	
电网同意吸收丰水期及夜间电能时	0.8~0.90
电网限制丰水期及夜间电能时	0.7~0.8
4、独立运行的日调节及无调节的电站	0.6~0.7

考虑到南令河一级电站属于联网电站（不属于独立运行的电站），是无调节性能的，那么即使在电网同意吸收丰水期和夜间电能的时候，电站的有效电量系数最高是 0.90。

当地其他同类型已投产水电项目的有效电量系数基本是在 0.75 到 0.85 之间。

由此可见，南令河一级电站 0.9 的有效电量系数取值实际上是比较乐观的估计。做这样的估计一方面是考虑到当地电网容量在不断扩大，另一方面是考虑到将来也许会存在西电东输的可能性，因此为南令河一级电站确定了一个非常理想情况下的有效电量系数。

2，线损和厂用电率

南令河一级选择的线损理论计算如下所示：

有功损失计算公式如下所示：

$\Delta P=P^2RL/1000U^2\cos\phi^2$

式中：ΔP：有功损失（kw）

R：单位输电线路电阻，本项目使用的是 LGJ120 导线， R=0.27/KM

L：输电线路长度 12KM

U：输电电压等级 35KV

P：输电容量：10000KW

cosφ：功率因素 0.8

计算结果为：ΔP=413kw

转换为电量为 413×4509=186.22 万度

线损率为：1862.2/（8*4509*0.9*（1-0.68%））=6%.

厂用电率考虑了以下因素：

（1） 生产用电：

① 压缩气体系统：用于机组的正常制动用气，机组检修密封等，共 3 万度。

② 技术供水系统：用于发电机冷却器、轴承冷却器，水轮机主轴密封等用水，共 10 万度。

③ 排水系统：用于厂房渗漏排水和机组检修排水二部分组成，共 0.5 万度

④ 油系统：用于机组润滑，散热和操作用油等，共 3 万度。

⑤ 机械修理设备：用于机组修理等，1 万度

⑥ 厂区照明：1 万度
⑦ 办公：1 万度
小计：19.5 万度

（2） 生活用电：
① 照明：1 万度
② 卫浴：1 万度
③ 其他：洗衣，电脑等 0.5 万度.
小计：2.5 万度

合计 22 万度。厂用电率=22 万度/8*4509*0.9=0.68%。
综合考虑，线损和厂用电率取 5%，是保守的。

3. 年运行小时数

南令河一级电站年运行小时数的计算过程在《南令河电站水文分析计算报告》和《南令河一级电站可行性研究报告》第四章中有详细描述，在此做简要说明如下：

（1） 根据《小水电水能设计规程》（SL 76-94），本电站建成后并入南方电网运行。本电站规模较小，由于电站容量在系统中所占甚微，故本电站设计保证率取为 80%。

（2） 根据《南令河电站水文分析计算报告》，勐董水文站的地理位置、气候因素、地质情况与本电站所在地相似，因此本电站在进行径流计算时采用勐董水文站的水文资料。

（3） 采用面积比拟加降水修正方法，通过勐董水文站 31 年（1972-2002）的日平均流量数据，可计算出本电站的流量。本电站从 5 个引水区取水，每个引水区的流量分别计算，本电站取水口流量为 5 引水区流量总和。将勐董水文站 31 年的日平均流量进行排序，选取出现频率分别为 10%、50%、90%三年的流量作为丰、平、枯流量用于计算本电站流量。将丰、平、枯三年电站取水口流量数据按从大到小排列，分别计算每个流量的出现频率（某流量出现频率=等于或大于该流量的个数/（总流量个数+1）），从而可以得到电站取水口的流量-频率曲线。具体计算方法和参数请见《南令河电站水文分析计算报告》第一至第三章，电站取水口流量-频率曲线见《南令河电站水文分析计算报告》图 3.4.6。

（4） 确定电站水头。根据电站前池水位的高程（海拔高度）和电站机组安装位置和尾水的高程，可得到本电站的水头。电站水头还要考虑因为管径、拦污栅引起的水头损失。计算过程见《南令河一级电站可行性研究报告》4.2.2。

（5） 确定出力系数。根据《南令河一级电站可行性研究报告》4.2.1，本电站出力系数为 8.4。

（6） 计算出力 N，公式为 N=9.8*日平均流量*水头*出力系数。采用上述第 3 点确定的电站取水口流量-频率曲线，对每个流量数据进行出力计算，则可以得到出力-频率曲线。根据上述第 1 点确定的保证率 80%，可在出力-频率曲线上得到当频率为 80%时，出力为 520kW，该出力即为保证出力。

（7） 根据经验，电站的运行时间应为 4000-5000 小时，考虑全年 8760 小时，则频率为 45.66%-57.08%。从出力-频率曲线上，可以查得本电站装机容量为

10MW-6.4MW，根据可选取的水轮机组型号，确定10MW、8MW、6.4MW三个装机方案进行比较。

（8） 电站发电量计算、使用上述第3点得到的日平均流量计算每日的发电量，日发电量=出力N*24小时。需要注意的是，当某日的流量大于某型号机组的额定流量时，只能采用机组的额定流量进行发电量计算，当某日的流量小于某型号机组的额定流量时，则采用该日流量进行发电量计算。

（9） 为三个方案分别进行建设投资、发电量、经济效益计算，从而可对三个方案进行比较。比较的结果请见《南令河一级电站可行性研究报告》4.3节。通过比较，8MW装机时本电站具有最优的投资收益比。因此可确定本电站装机为8MW。

（10） 通过上述第8点，已计算出电站装机为8MW时，年发电量为3607万kWh。年运行时间=发电量/装机容量=4509小时。

云南省临沧市水利水电勘测设计研究院

二00九年十二月七日

The explanation of the coefficient of effective power, transmission loss rate and internal power consumed rate of Nanlinghe 1st level hydropower station

1， Coefficient of effective power

Nanlinghe 1st level hydropower station located in Cangyuan County, Yunnan Province. The installed capacity is 8MW.

the theoretical electricity generated are calculated by water flow rate multiply the natural water head, turbine efficiency, generator efficiency, in which, the water flow rate is the average water flow rate of three represent abundant, normal and dry years based on years of statistical hydrological information. Usually, the theoretical electricity generated is higher than the actual electricity generated because of the following reasons:

- The amount and stability of water runoff;
- The power plant's own performance, i.e., whether they have multi years/annual/seanonal/ weekly/daily regulation capacity or not. Normally, the grid is more inclined to receive the electricity supplied by the regulating hydropower station than non-regulated run-of-hydropower station;
- The situation of the grid, which include the capacity of the grid, the maintenance and management of the grid;
- The management level of power station which include the maintenance of the mechanical and electrical equipment, the safety of hydraulic structures, the skill level of the operator; the unit repair time and the rate of accidents, etc.;
- The impact of the natural environment, which include protection situation of the vegetation within the catchment area, the construction of the reservoir on the upstream and the human activity and so on.

Some factors can be controlled such as the improvement of the management, the environment protection. Some factors are hard to be controlled, such as the grid capacity. It showed that the actual electricity generation of almost all the small hydropower station cannot reach the theoretical electricity generation, especially in the region which mainly comprised of the hydropower station.

To estimate the actual electricity generated reasonably, a coefficient of effective electricity generation is specified in the “Economic Evaluation Code for Small Hydropower Projects (SL16-95)” dated on 1 July 1995, which is currently still valid. Based on this the coefficient of effective electricity generation values for hydropower plants are listed in the table below:

Project type	**Coefficient of effective electricity generation**
1. Grid connected, annual/multi year regulating hydropower plants	0.95-1.00
2. Grid connected, seasonal regulating hydropower plants	0.90-0.95

3. Grid connected, monthly/weekly/daily/no regulating hydropower plants:	
The grid will accept all electricity generated in rainy season and night	0.80-0.90
The grid will only accept part of the electricity generated in rainy season and night	0.70-0.80
4. Stand alone hydropower plants, daily/no regulating capacity	0.60-0.70

Considered Nanlinghe 1st level hydropower station is grid connected with no regulation function, so even when the grid will accept all electricity generated in rainy season and night, the highest coefficient of effective power is 0.9.
The coefficient of effective power of the other similar local hydropower stations range from 0.75 to 0.85.
According to the above analysis, the 0.9 of the coefficient of effective power is optimistically.

(1) the 5% transmission loss and internal consumption

the main transmission loss can be calculated with the formula:

$$\Delta P = P^2 RL/1000U^2 \cos\varphi^2$$

where：Δ P：the main transmission loss（kW）;

R:the resistance of the transmission line， for the Project, R is equal to0.27/km;

L：the length of the transmission line, which is 12km for the Project;

U：transmission voltage, which is 35KV for the Project;

P：transformer capacity which is 10000kVA for the Project;

cosφ：power factor, which is 0.8

The result is 413kw, transforming to electricity is 0.413MW×4509h=1862.2MWh.

And the transmission loss rate is calculated with the following formula:

Transmission loss rate =1862.2MWh/(8MW*4509*0.9*(1-0.68%[1]))= 6%.

The following factors have been considered for internal power consumption:

（1） electricity consumption for production:

- Compressed gas system: about 30MWh.
- Water supply system: about 100MWh.
- Drainage system: about 5MWh.
- Oil system: about 30MWh.
- Mechanical Repair Equipment: about 10MWh.
- Plant lighting: about 10MWh.
- Office using: about 10MWh.

Totally it is about 195MWh.

（2） Electricity consumption for living

[1] As described follow, the estimated internal consumption rate is 0.68%.

- Lighting: about 10MWh.
- Bathing: about 10MWh.
- Others: about 5MWh.

Totally it is about 25MWh.

According to the above calculation, the internal electricity consumption is 220MWh. At the same time as the internal consumption rate is equal to the amount of internal electricity consumption divided by the electricity generation, i.e., the internal electricity consumption rate=220MWh/(8MW*4509h*0.9)=0.68%.

Comprehensive consideration, it is conservative to adopt 5% for the transmission loss rate and internal electricity consumption rate.

3. Operation hour

The calculation process for operation hour has been described in detail in the *hydrological analysis and calculation of Nanlinghe Hydropower Station* and *Feasible Study Report of Nanlinghe 1st level Hydropower Station.* Brief explanation is showed as follow:

(1)The Project will be connected to Southern China Grid. As the Project is a small scale hydropower station and the capacity accounts for small in the Southern China Grid, according to the Chinese Hydro Energy Design Code for Small Hydropower Projects (SL74-94), the guarantee rate is taken 80%.

(2)According to the *hydrological analysis and calculation of Nanlinghe Hydropower Station,* Mengdong Hydrological station has the same location, climate, geology situation as the Project, so the hydrological data of Mengdong station has been used for the runoff calculation.

(3)By MengDong Hydrological Station 31 years (1972-2002) daily average hydrological data to calculate the flow rate. The hydropower station will get water from 5 water catchments. The flow rate of each water catchment will be calculated separately and the flow rate of the station is the sum of the flow rate of the 5 water catchments. First, ranking the 31 years daily average flow rate of the Mengdong Hydrological Station and selecting the flow rate of the three years in which the occurrence frequency is 10%, 50% and 90% to calculate the flow rate of station. The 10% occurrence frequency year is rainy year, the 50% occurrence frequency year is normal year and the 90% occurrence frequency year is dry year. Secondly, ranking daily flow (Q) data for these three years and then calculate the occurrence frequency of each flow (occurrence frequency of the Flow=the number of the flow which is equal to or larger than the Flow/ (the number of the flow+1)) . The detailed calculation process please refers to the chapter 1-3 of the Hydrologic Calculation Report of Nanlinghe Power Station. The station flow-frequency curve please refers to the figure 3.4.6 of the Hydrologic Calculation Report of Nanlinghe Power Station.

(4) Identifying water head (H) according to local measuring. The water head of the Project is the height of the pressure pool minus the electricity generation units and the tail water. At the same time water head loss caused by the pipe diameter and trash rack. The calculation processes please refer to the FSR4.2.2.

(5) Identifying the output coefficient. According to the Feasible Study Report of FSR 4.2.1, the output coefficient of the Project is 8.4.

(6) Calculating daily capacity for the three years by using equation N=8.4*Q*H. where, Q is the daily average flow; H is the water head. The capacity-frequency curve will be get based

on the flow-frequency curve determined on the step3. When the guarantee rate is 80%,the capacity is 520kw, and this is the guarantee capacity.

(7) Since the operation hour of a hydropower station should be 4000-5000, i.e. the load factor should be 45.66%-57.08%. From the capacity-frequency curve identified in (4), it can be read the capacity of the Project should be 10MW to 6.4MW.

(8) Calculating the electricity generation. The daily electricity generation is equal to the daily average capacity multiplying 24h. When the daily flow is larger than the rating flow, only the rating flow can be used for calculation and when the daily flow is smaller than the rating flow, then the daily flow is used for calculation.

(9) According to type of turbine and generator, three options, 10MW, 8MW, and 6.4MW are selected to analysis and compare. Considering power generation, investment, construction, the 8MW (N_{final}) option results best water resource utilization. Please refer to chapter 4.3 of FSR.

(10)According to the above step 8, when the installed capacity is 8MW, the electricity generation E is 36070MWh. Operation hour can be achieved by dividing E by N_{final}, which is 4509h.