An Improvement of Reliability for Electricity Distribution System in Phone Thong District, Lao PDR

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***Abstract*—The purpose of this study is to predominately investigate the power systems in the Bang Yo substation (Feeder7 Phone Thong) of the Lao PDR in correspondence to the 22 kV distribution system development plan of Electricity du Laos (EDL) during the period 2015-2020. The investigation will specify the additional distribution line projects implemented to satisfy the N-1 contingency criterion, justify the economic viability of the system's impact, while make present additional projects that will facilitate the improvement of the quality and reliability of such regional networks. In the investigation, the steady-state power flow analysis and distribution system reliability assessment for Bang Yo's substation power systems were conducted during the period of peak demand. As a direct result from the system reliability assessment, the improvements of system loss saving, Energy Not Supplied (ENS), System Average Interruption Frequency Index (SAIFI), and System Average Interruption Duration Index (SAIDI) after reinforcing the systems with each of the additional projects were obtained. Additionally, in the economic evaluation of each additional project during the corresponding period, the calculations of the Economic Internal Rates of Return (EIRRs) on account of the system reliability improvement were performed in correspondence to the interest rates of the Bank's loan of 10%**

***Index Terms*—electricity distribution system reliability, SAIFI, SAIDI, ENS**

I. Introduction

The high voltage distribution systems in south area are connected with four (4) major hydropower plants, namely Xeset 1 (45 MW), Xeset 2 (76 MW), Xeset 3 (23 MW) and Houylamphane (88 MW). These plants supply electric energy mainly to South area is delivered through various 115/22kV substations. High voltage in the Champasak province is delivered through 115/22 kV substations, while high voltage in the areas BanNa, BanHad, Jengxay, Paksong, Bang Yo and Champasak are delivered through 115/22 kV Bang Yo substation [1]. The overview of the existing system in south area is shown in Fig. 1

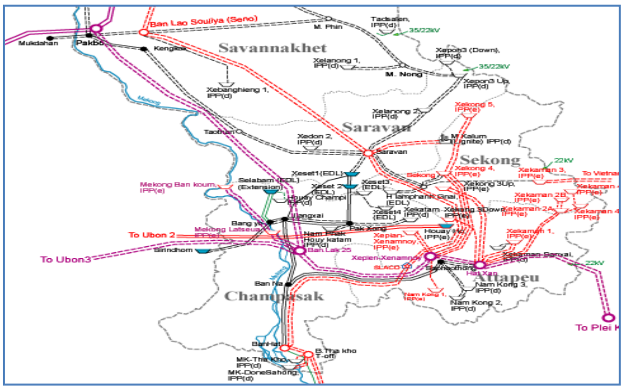

Figure 1. The overview of existing system in southern area of Lao PDR

The 115/22kV Bang Yo substation is located in the Champasak province, southern of Lao PDR. Bang Yo substation consists of two unit of 115/22kV Power Transformer (22 MVA) and composts of 7 feeders (22kV) that supply power to Pakse and Phone Thong districts. The peak load of this substation is 38.6 MW. The single line diagram of Bang Yo substation is shown in Fig. 2, as well as overview of the existing system for Bang Yo substation.

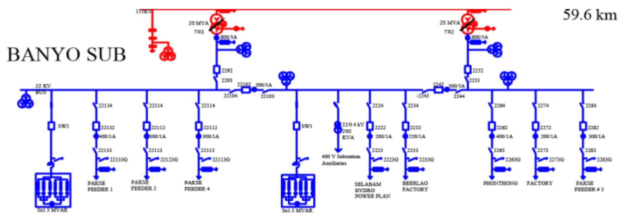

Figure 2. Single line diagram of Bang Yo substation in 2015.

Previously, the distribution system of 22 kV has experienced failure many times throughout the year, causing power outages and delays in maintenance, that result to mass amounts of dissatisfaction amongst affected local communities. However, to make distribution system more stable and operate without failure, a study analysis should be conducted to improve

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22 kV distribution system of Bang Yo's substation. This study will also in particular outline improvements to the distribution lines of Phone Thong District (feeder7).

Most of the existing distribution lines of Phone Thong have been operating for more than 34 years from a distribution system of a single circuit. It is for this reason that there is a lack of reliability of the system, as indicated from its frequent power failures that causes disruptions to the people in the area. Disruptions not only impact residents, but also industrial business and commercial buildings that depend on power to operate their day to day services. The Phone Thong composes of 1 feeders7 for supply power to 71 villages, the Transformers is 253 units, and the distribution lines is 245 km/circuit.

Consequently, not only does total system see failures and voltage drops at the end users are significantly high, but the regional grinds are also considerably unreliable. It is essential to increase the electrification ratio in several rural areas and to effectively augment the national energy security. Furthermore, the appropriate distribution system reinforcement and expansion will be able to reduce the system outage costs and to make electricity tariff reasonable [2]

To investigate the 22 kV distribution systems of Phone Thong and suggestions to adjust existing system in order to improve the system reliability of such system networks is shown in Fig. 3.

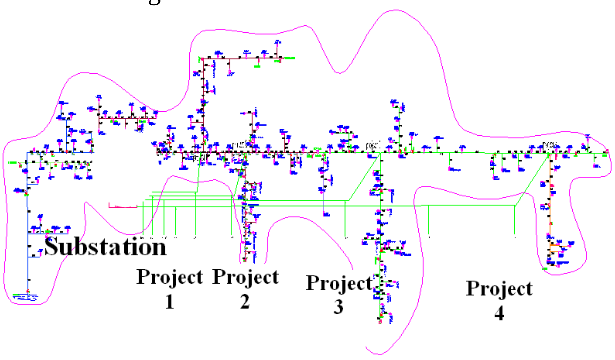

Figure 3. The single line diagram planning of Phone Thong in 2015

II. Methodology

The main objectives of this study are to investigate the distribution system development plan of EDL, based on the N-1 contingency criterion. The adjustment in this plan is to improve the reliability of such regional networks for the given years based on the economic justification, and the distribution system reliability assessment. This study is performed so as to investigate and adjust the 22 kV. The distribution system development plan of EDL, specifically the 22 kV distribution development projects in the Phone Thong district regions in horizon 2015-2020.

A. *Distribution System Reliability Assessment*

To eliminate or, at least, to reduce the critical outage occurrences on the distribution network is one majority of consideration in the distribution system development planning. Namely, the appropriate alternatives of the reconstruction and reinforcement of the existing distribution facilities, and/or the construction of the new ones will be able to improve the network-service capability. The improvement should be considered in the terms of the avoided costs of the service outages. These avoided outage costs are related to the distribution system reliability indices; e.g., System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), and Energy Not Supplied (ENS) [3]-[10].

1) The System Average Interruption Duration Index (SAIDI)

$$SAIDI = \frac{\sum U_i N_i}{\sum N_T} \tag{1}$$

[Hrs/customer/year] or [Hrs/100 circuit -km/year]

where

U_i = the annual outage duration (Hrs/year) of the distribution line *i*,

N_i = the number of circuit-100 kilometers of distribution lines *i*.

2) The System Average Interruption Frequency Index (SAIFI)

$$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_T} \tag{2}$$

where

λ_i = the outage rate (Occurrences/year) of the distribution line *i*,

N_t = the number of circuit-100 kilometers of distribution lines *i*,

$\sum N_T$ = total number of customers served or interrupted.

3) Energy Not Supplied Index (ENS)

$$ENS = \sum L_{a(i)} U_i \tag{3}$$

[kWh/year]

where

$L_{a(i)}$ = the average load (kW) not supplied if tripping the distribution line *i*,

U_i = the annual outage duration (Hrs/year) of the distribution line *i*.

4) Economic justification

A Distribution system development projects is designated to mainly enhance the capability of delivering electric power to serve the growing demand, to reduce the system losses, and to improve the system reliability. The benefits from the capability enhancement, the reduction in system losses, and the system reliability improvement, are of use to justify the economic viability of such a project. In the economic justification, the approaches to determining the Economic Internal Rates of Return (EIRR) of the project are applied suitably.

The EIRR of a project is regarded as the discount rate which equalizes the present values of the consolidated cost and benefit streams of the projects. The present values of the consolidated cost and benefit streams should be:

$$\left[\sum_{n=1}^{n=(N-M+1)} \frac{B_n - C_n}{(1+i)^n}\right] + \frac{S_v}{(1+i)^{(N-M+1)}} - C_{proj} = 0 \quad (4)$$

where

i = the economic internal rate of return (EIRR)

= the interest rates of the World Bank's loan;

M = the commissioning year of each project;

N = the year that is the end of the period extended from the final year of the power development plans;

C_n, B_n = the operation and maintenance costs (O&M) and benefit stream at the end of the n^{th} year, respectively, US$;

C_{proj}, L_{proj} = Project cost (US$) and project life (Years) of each project, respectively;

S_v = Book value of the distribution facility at the N^{th} year, US$;

$$S_V = C_{proj} - \frac{C_{proj}}{L_{proj}}(N - M + 1) \quad (5)$$

Energy Loss = Capacity Loss x 8,765 x Loss Factor (6)

Loss Factor = 0.3(Load Factor) + 0.7(Load Factor)^2 (7)

Load Factor = 0.6

(obtained from EDL's system planning office)

The costs of losses obtained from EDL's system planning office are as follow:

- Capacity Cost = 85 US$/kW-yr
- Energy Cost = 0.065 US$/kWh-yr

The 22 kV distribution lines failure rate (failure data per 100 km/year) are as follow:

- Sustained failure frequency = 56 (1/annual)
- Repair duration (mean) = 32 Hrs

Failure data for the 115/22 kV substations are as follow:

- Failure rate frequency = 0.0063 (1/annual)
- Additional failure data per connection
- (failure rate frequency = 0.05) (1/annual)
- Repaired duration (mean) = 7.3 hrs.

III. Case Study in Lao PDR

This paper will focus on the distribution system development planning for the 22 kV distribution development projects in the PhoneThong district regions of Champasak Province in the horizon 2015-2020, as shown in Fig. 3.

Determination of electrical reliability by using excel Calculate energy loss results, Energy Not Supplied (ENS), System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) after reinforcing the systems with each of the additional projects were obtained.

But the project is reduced in Table I compared with a loss of power, ENS, SAIFI and SAIDI.

TABLE I. Results of the Calculations ENS, SAIFI, SAIDI, Power Loss for Project 1-4

Sub Project	**ENS**	**SAIFI**	**SAIDI**	**Power Loss**	Fiscal Year
Project1	57,464	975	46,051	0.63	2015-20
Project2	35,587	557	27,504	0.52	2015-20
Project3	34,392	610	30,071	0.59	2015-20
Project4	21,842	585	30,071	1.12	2015-20

So, EIRR calculations for the distribution system subproject 1-4 is shown on the Table II.

TABLE II. Subproject Cost and EIRR.

Subproject	**Length (km)**	**Subproject Cost (USD)**	**EIRR (%)**
1	44.00	885,911	11.15%
2	4.00	80,537	39.28%
3	2.76	55,571	47.17%
4	3.00	60,403	60.21%

The results of EIRR of individual subproject from the reduction of system losses, saving and to reduce the system outage costs or Energy not Supplied (ENS) of power system have been checked and its results of Economic Internal Rate of Return (EIRR) of each subproject have been compared with interest of World Bank (the interest of World Bank's loan =5% for Lao PDR).

The EIRR of all subprojects should see a greater interest from the World Bank's loan (5%), and these subprojects should installed in to distribution system development plan of EDL's Champasak, to improve the reliability of supply are needed.[11]-[12]

IV. Conclusion

This study proposes the investigation of the distribution systems in the Bang Yo substation of Champasak branch corresponding to the 22 kV distribution system development plan of Electricite du Laos (EDL). This paper has specified additional distribution line projects implemented to meet N-1 contingency criterion, and the provided the justification of the economic viability of the system reinforcement facilitating the improvement of the quality and reliability of such regions networks for the years 2015-2025.

In the system reliability assessment, the improvements of system losses saving, Energy Not Supplied (ENS), System Average Interruption Frequency Index (SAIFI), and System Average Interruption Duration Index (SAIDI) after reinforcing the regions' economic evaluation of each additional distribution line project during the corresponding period, the calculations of the Economic Internal Rate of Return (EIRR) on account of the system reliability improvement were obtained from which the cost stream consists of the capital cost, and the operation and maintenance costs, whereas the benefit stream

comprises the combined incremental revenue made available from the construction, and the system loss saving and ENS reduction; corresponding to the interest rates of the Bank's loan of 10%, 12% and the avoided outage cost of 0.065 US$/MWh-yr (adopted from EDL).
From in the justification using the economic evaluation based on the corresponding EIRRs of each additional project, only projects 1, 2, 3 and 4 tend to be economically viable as the EIRRs of the project are greater than the corresponding interest rates of the Bank's loan.

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