CHAPTER 3

Power System Analysis

The reliability indices such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration index (SAIDI) and Customer Average Interruption Duration Index (CAIDI) are calculated based on the record outage in each distribution substation. The SAIFI, SAIDI and CAIDI in Vientiane, Capital of the year 2013 are shown in the table 3.1

Table 3.1 Summary of reliability in Vientiane Capital 2013

Name of substation	SAIFI (time/customer/year)	SAIDI (hour/customer/year)	CAIDI (hour/year)
Phonthong	4.78	24.63	5.15
Thanaleng	4.33	160.50	37.07
ThaNgon	3.79	74.51	19.63
Khoksa-at	3.04	58.79	17.62
Naxaythong	13.95	466.22	33.42
Total	**5.83**	**658.59**	**112.89**

3.1 Data of the case study for analysis and improvement

The reliability analysis of distribution system has connected network by switching which results of consider connect switching. Reliability indices from calculate are composed SAIFI, SAIDI and CAIDI. Including analysis, cost of network system as such: outage cost, investment cost and total cost.

Reliability analysis involves determining, generally using statistical methods, the total electric interruptions for loads within a power system. The interruptions are described by several indices that consider aspects such as:

- The number of customers;
- The connected load;

- The duration of the interruptions;
- The amount of power interrupted; and
- The frequency of interruptions.

The outage events in the distribution system are caused mainly by the equipment, animal, tree, traffic accident and natural disaster. Accordingly, to reduce for causing that should be modified and improved, using adding equipment prevents and maintenance of the distribution system. Analyses reliability indices of these databases are the basic data of particular elements may be determined for improvement of reliability which adding equipment prevents and maintenance of the distribution.

As the investment for the reliability increase is making in facilities more, the reliability would increase more. However, seeking too high reliability, increase sometimes requires the huge cost, making the countermeasures unfeasible.

Figure 3.1 shows the reliability of the distribution system improvement. Outage collection data record demonstrates the cause outage of feeder and the customer number effect the distribution system. The loaded data include power factor, voltage and etc. Those are usually obtained on Medium Voltage (MV) feeder at 115kV/22kV substation and Low Voltage (LV) feeder 22kV/0.4kV transformers. The collected outage data are analyzed based on effected customer and outage numbers. The effected customer numbers were estimated to input in the software.

The facilitated distribution system data are collected regarding to the geographic location of routes line with GPS measurements. The electric data on feeders such as conductor type or lengths of the sections. The conductor’s type and transformers is based data portion on the date and time of interruption, data operating equipment, outage duration, interruption causes and the feeder length from the collected substation. These are resulted to reliability indices arranged on the data system to develop and analyze with DIgSILENT Power Factory program.

The reliability improvement is determined case studies with assumptions of expected effective reliability, increase to the policy of reliability, increase such as maintenance and distribution protection distribution system calculated in different cases of reliability increase.

The economical evaluation phase is consisted of reliability improvement costs and the investment cost. The benefit of reliability, increase and the countermeasures cost are calculated from reliability, increase number and the additional facilities for the reliability distribution system increase. The study concepts are shown as in Figure 3.1 below:

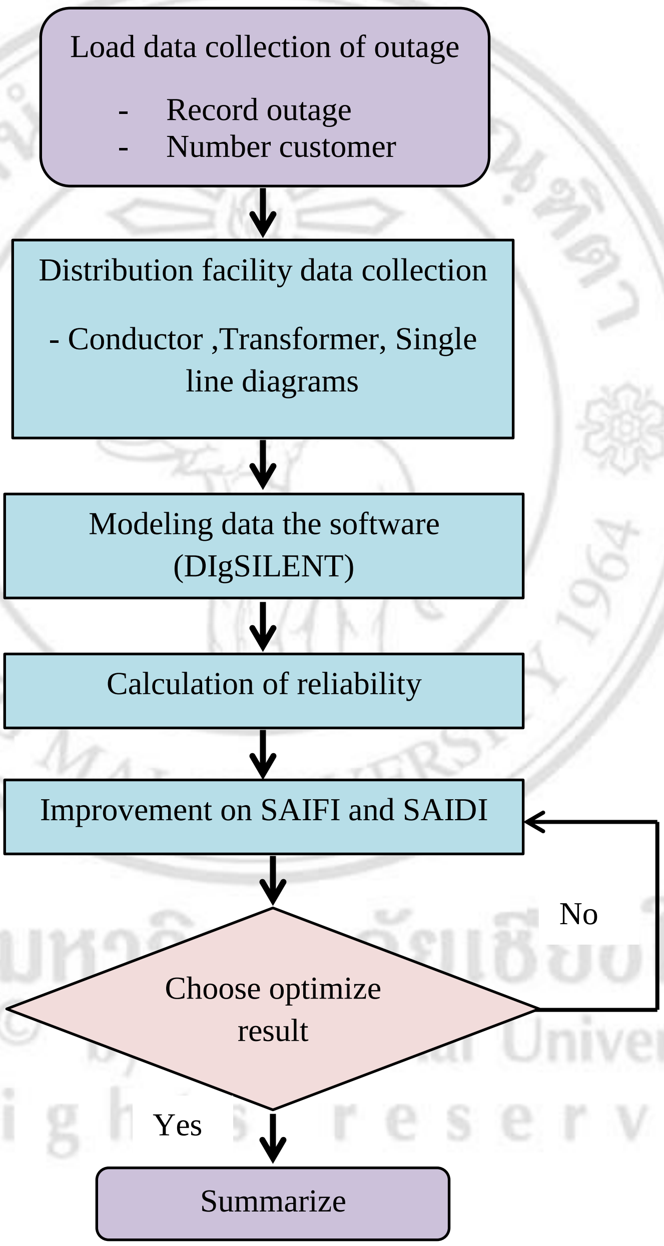

Figure 3.1 flowchart of improved methodology.

3.2 Load dispensation

In general, distribution network spread out widely around the area. So it is difficult to grasp the loading situation throughout the network accurately. In order to calculate the reliability indices in MV distribution network, power flow of section is required. For this purpose, load data of each MV/LV transformer are needed to grasp the power flow. Once the load of each transformer has been given, power flow of each section is determined can be calculated as well.

3.3 Procedure of DIgSILENT Power Factory program analysis

The MV reliability indices analyzed with DIgSILENT power factory program following the process described below in due order.

1. Model feeders into DIgSILENT Power Factory and carry out load allocation to the sections of the feeders.

2. Conduct analysis of reliability indices.

3. Simulate the case with countermeasures to find improvement of reliability. Conceivable countermeasures are listed in due order as follows:

- Consider utilizing the planned 115 kV/ 22kV substations and main feeders as much as possible.

- Carry out switching optimization.

- Select the countermeasures for increased reliability with at sections of feeders.

- Conduct simulation to position the equipment prevent, such as: Recloser and disconnect switching with the locations of equipment installation.

3.4 Basic procedure of DIgSILENT Power Factory

The DIgSILENT Power Factory has originally been designed as a complete package for user procedure for completing a reliability assessment. However, the program is also power distribution system analysis and can perform several types of analysis on reliability indices that are operated in radial, looped or meshed configurations. The modules that EDL has obtained and utilized for reliability indices analysis includes per customer interruption, optimal re-closer and disconnects switching placement to optimization.

Software operations are described in the DIgSILENT Power Factory reference manual and user manual accompanied by the software licenses. Here, the basic user procedure for completing a reliability assessment consists of the following steps as shown in Figure 3.2.

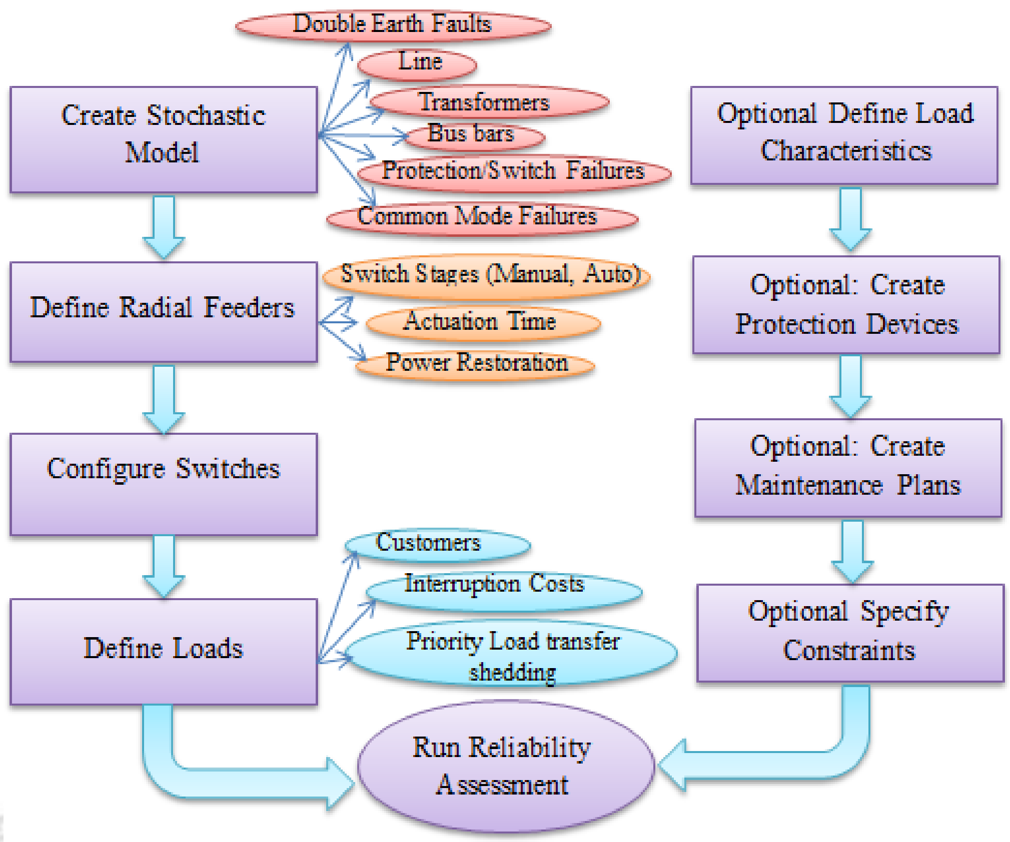

Figure 3.2 Reliability assessment user procedures[19].

3.5 Reliability analysis procedure

The Reliability analysis procedure considers the network topology; protection systems, constraints and stochastic failure and repair models generate reliability indices. The system state data describe the expected frequency of occurrence of the system state and its expected duration. However, the duration of these system states should not be confused with the interruption duration. That analysis is combined with the data that is provided by the system state generation module to create the reliability statistics including indices such as SAIFI, SAIDI and CAIFI.

The analysis of reliability indices will consider of each feeder using the reliability assessment tool also known as reliability analysis consists of the following:

- Failure modeling,
- Load modeling,
- System state creation,
- Failure Effect Analysis (FEA),
- Statistical analysis.

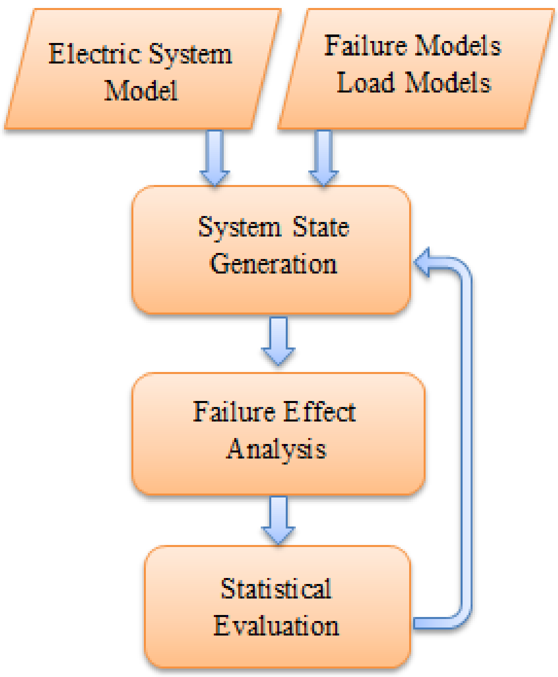

Figure 3.3 Assessment of Power Factory Reliability [19].

The reliability analysis calculation flow diagram is depicted in Figure 3.3. The failure models describe how system components can fail, how often they might fail and how long it takes to repair them when they fail. Basically, this means any model on which a power flow analysis can be performed. Secondly a failure model has to be input. This input consists of the failure statistics defined for each component. Normally characteristic is an interruption frequency and an outage duration parameter pair, but other varieties also exist. This characteristic can consist of a few possible load demands, or can be based on a user defined load forecast and growth scenarios.

3.6 Conductor characteristics

The conductor database of Power Factory requires the following four types of parameters to evaluate the overhead line characteristics.

- Rated voltage
- A rated current
- Parameters per length 1, 2 sequence
- Parameters per length zero sequence

3.7 Types of conductor

Several types of conductors are used in the MV system of EDL, the generally used conductors based on British standard and Thai YAZAKI standard.

The recent major distribution projects generally used conductors based on British Standards. The different types of conductor have also been used in earlier projects, such as German standard. Table 3.2 shows the conductor characteristics that are categorized as ACSR 150 mm^2. EDL often describes the conductors with only cross-section size in the single line diagram. Therefore, it is impossible to specify the type of conductor. The electrical characteristics are quite different by each conductor.

Table 3.2 The conductor characteristics of EDL

Medium Voltage Conductor							
Type Conductor	α	Diameter (mm)	No. of stranding	GMRK (mm)	GMR (mm)	R 20 (Ω/Km)	Current kA
PIC 35	0.00403	6.95	7	0.726	2.523	0.868	0.149
PIC 50	0.00403	8.33	7	0.726	3.024	0.641	0.186
PIC 70	0.00403	9.73	19	0.758	3.688	0.443	0.237
PIC 95	0.00403	11.45	19	0.758	4.340	0.32	0.279
PIC 120	0.00403	12.95	19	0.758	4.908	0.253	0.321
PIC 150	0.00403	14.27	19	0.758	5.408	0.206	0.365
PIC 185	0.00403	15.98	19	0.758	6.056	0.164	0.429
SAC 25	0.00403	5.90	7	0.726	2.142	1.2	0.119
SAC 35	0.00403	7.05	7	0.726	2.559	0.686	0.150
SAC 50	0.00403	8.11	7	0.726	2.944	0.461	0.180
SAC 70	0.00403	9.73	19	0.758	3.688	0.443	0.225

Table 3.2: The conductor characteristics of EDL (Connect)

Medium Voltage Conductor							
Type Conductor	α	Diameter (mm)	No. of stranding	GMRK (mm)	GMR (mm)	R 20 (Ω/Km)	Current kA
SAC 95	0.00403	11.43	7	0.726	4.149	0.32	0.275
SAC 120	0.00403	13.05	7	0.726	4.737	0.253	0.315
SAC 150	0.00403	14.37	7	0.726	5.216	0.206	0.360
SAC 185	0.00403	16.08	7	0.726	5.834	0.164	0.415
SAC 240	0.00403	18.57	7	0.726	6.741	0.125	0.490
ACSR 25	0.0036	6.00	6	0.500	1.500	1.203	0.125
ACSR 35	0.0036	7.77	6	0.500	1.943	0.9090	0.129
ACSR 70	0.0036	10.98	6	0.500	2.745	0.4550	0.195
ACSR 150	0.0036	18.13	30	0.826	7.488	0.1830	0.335
ACSR 185	0.0036	26.00	26	0.809	10.517	0.1571	0.535
ACSR 240	0.0036	21.77	26	0.809	8.806	0.1218	0.560

DIgSILENT Power Factory software requires being input the following 4 types of parameters in conductor database.

- Positive Sequence Resistance (R_1)
- Positive Sequence Resistance (X_1)
- Zero sequence Resistance (R_0)
- Zero sequence Resistance (X_0)

3.8 Cost of power outage reduction

The cost of countermeasures against reliability indices increase is as shown in the following table. In the feasibility study phases, the precise cost estimation would be required.

Table 3.3 Cost of improvement in reliability

Items	**Unit cost**
Installation disconnects switching (DS) of MV lines	6,000 USD /set
Load Break Switch	3,500 USD /set
Re-closer	3,752 USD/set

3.9 Load modeling

The load element parameters that are used by the reliability calculation are a number of customers that each load represents and to classify load. The process of creating a load interruption cost characteristic.

Loads in a feeder are modeled as distribution load or spot load at each section. It is presumed that if there is a MV/LV transformer in a section, there is a block of distribution load. That is construed that modeling a load is the same as modeling a MV/LV transformer.

At this time, you do not need to set “Actual Load”, because it is assigned automatically by “Load Allocation” described in the next chapter. If you have measured load data for a MV/LV transformer, you can use that data as actual load. Following is a dialog box for load/transformer data. As seen in Figure 3.4.

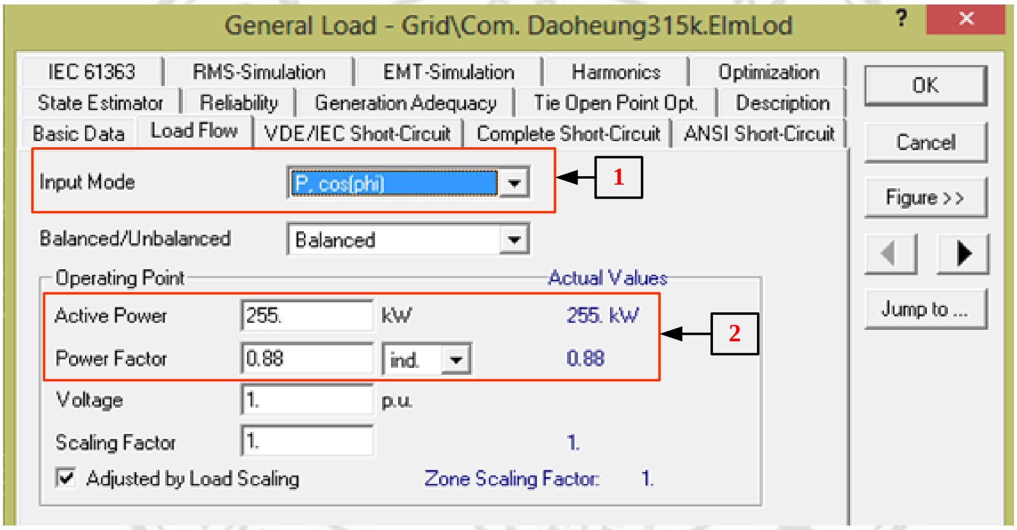

Figure 3.4 Input of load

3.10 Feeder modeling of reliability analysis

Feeder modeling is a main part of the preparation stage of DIgSILENT Power Factory analysis. Following information describe the essential information such as:

- Line diagram
- Route of distribution line
- Location of MV/LV transformer, capacity.
- Conductor types, length, etc.

In order to line by double click on picture line will dialog of the line so as Figure 3.5. Then, Select page “Basic Data” and input data of parameter line as such:

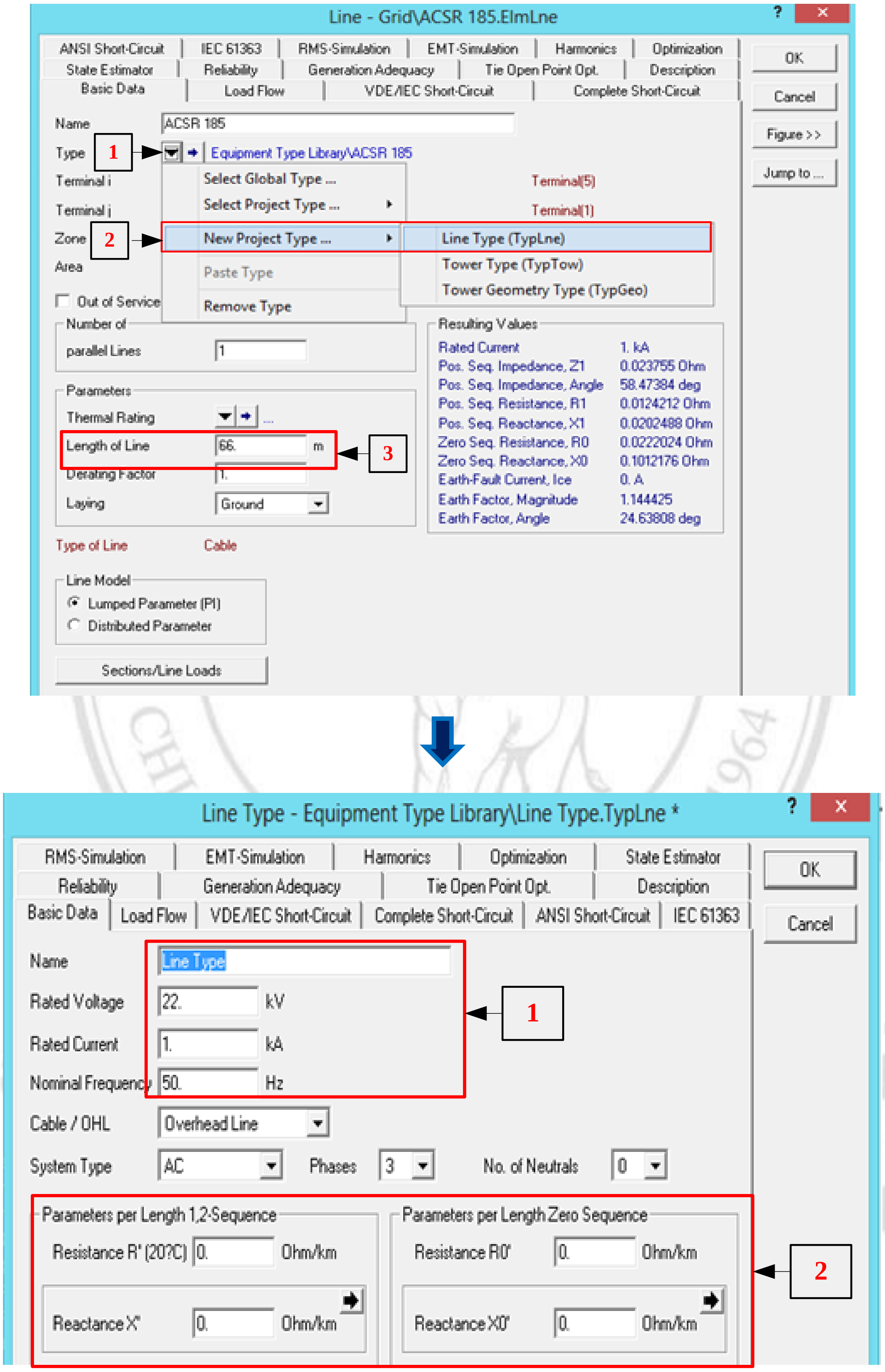

Figure 3.5 Creating type of line.

In order for load to be allocated along the feeder in proportion to the transformer connected kA, feeder load data at substation must be set before load allocation. Click "load" button for that purpose. The following dialog box appears as seen in Figure 3.6.

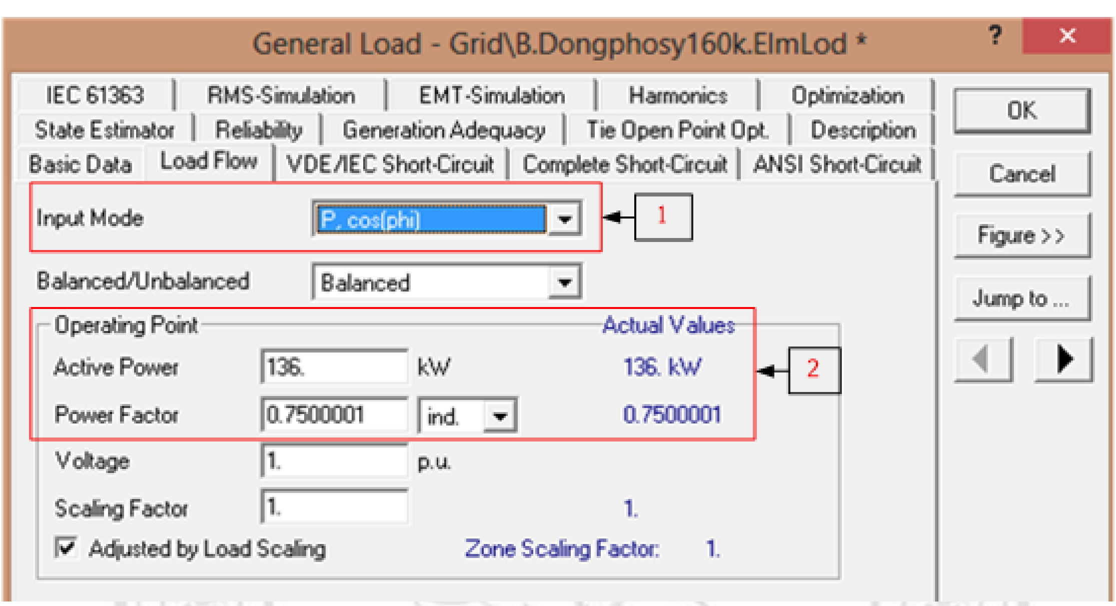

Figure 3.6 Load allocation dialog box.

3.11 Calculation load flow

The configuration of load flow calculation must be defined for use in the calculation as such parameter used in the calculation as seen Figure 3.7. Then click "Execute" to instruct the program to perform the configuration.

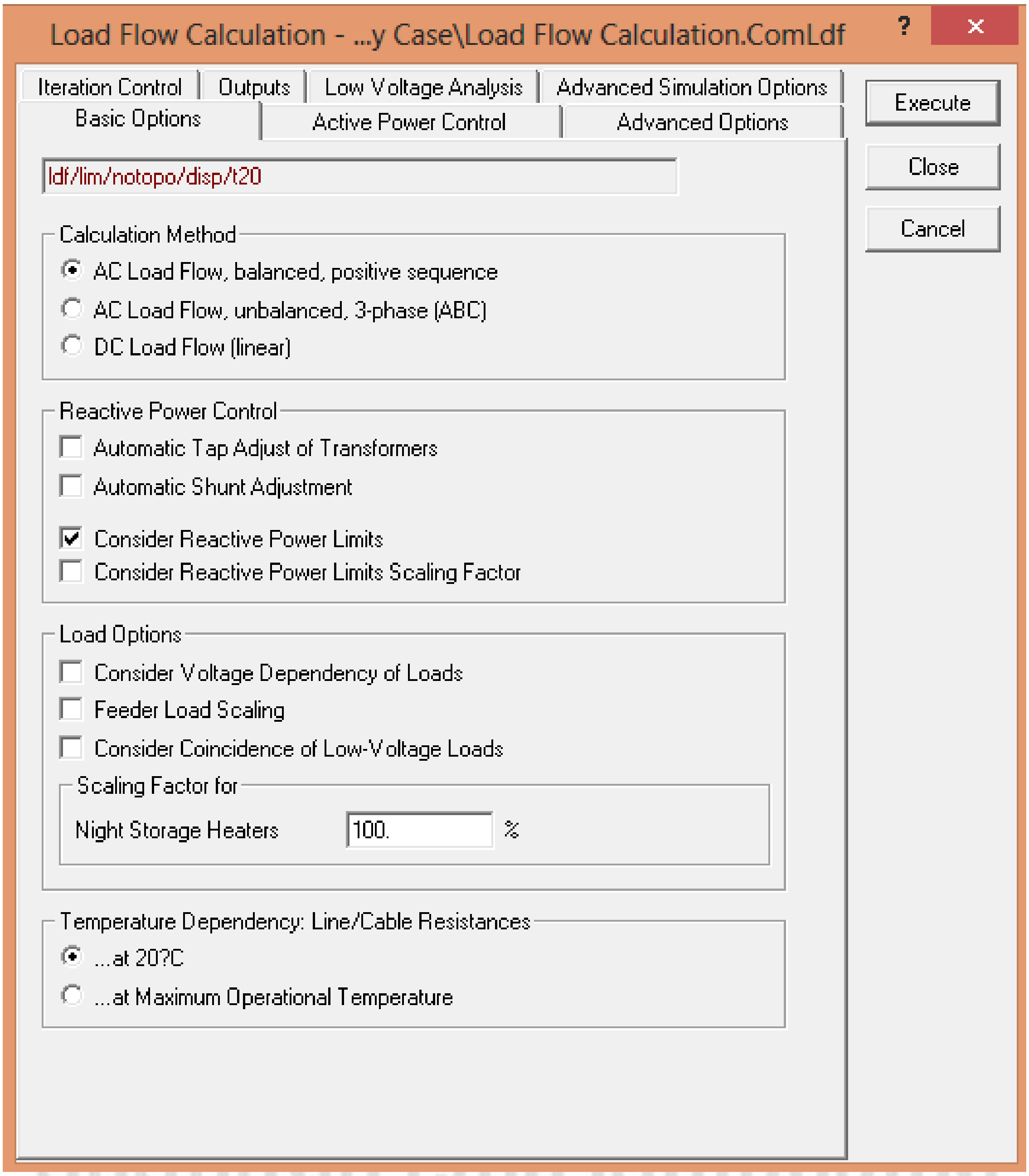

Figure 3.7 Calculation load flow in Tab “Basic Options”.

3.12 Running the reliability analysis calculation

In Power Factory the network reliability analysis is completed using the Reliability Assessment command. This command is found in the Reliability Analysis see Figure 3.8.

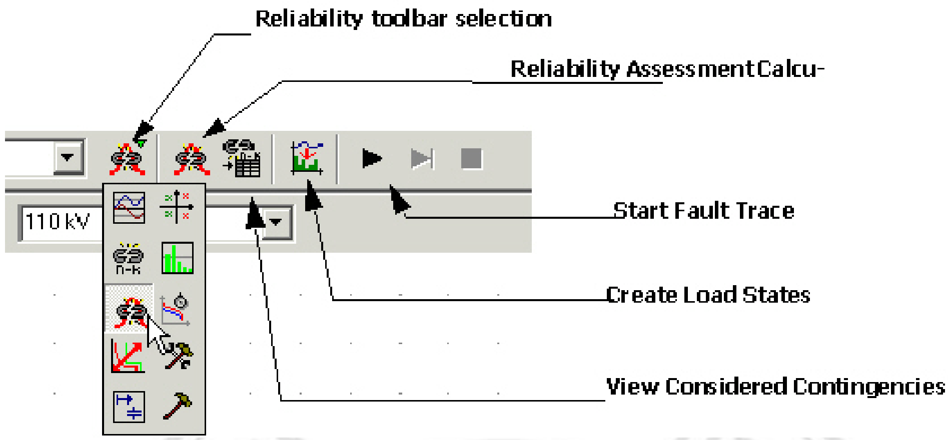

Figure 3.8 Reliability toolbar selection.

After the reliability analysis has completed, it is possible to view the fault clearance, fault separation, power restoration and load shedding actions completed by the algorithm for each contingency. To do this:

1. Click the “Fault Trace” button on the reliability toolbar. A list of available contingencies will appear in a new window.

2. Select the contingency to consider and click “OK”. The network will be initialized to the state before the inception of the fault.

3. Click the “Next Step” button to advance to the next system state. This will usually show the system state immediately after the protection has operated and cleared the fault.

4. Click the “Next Step” button to advance through more step, each click advances one time step.

5. To stop the fault trace, click the “Stop Trace” button.

The reliability analysis will try to remove overloading at components and voltage violations (at terminals) by optimizing the switch positions in the radial system. If constraints occur in the power restoration process, loads will be shed by opening available switches. This option is the recommended analysis option for distribution and medium voltage networks.

3.13 Analysis and finding the appropriate of equipment protection location.

The position analysis of equipment protection is switched ON/ OFF in the system. The aims to lessen the amount of customs impact on electricity utilization become to lowest by calculating of magnitude and the right equipment.

3.13.1 The overcurrent protection device in the power system.

Power system protection is essential to act eliminated malfunction or fault currents away from the distribution system. The failure of malfunction divides two types such as: main defense and defensive back up.

The main defense is to protect when malfunction have first by the relay in protection area fault currents away. Therewith, instructed the circuit breakers cut the fault currents of the power system.

The defensive back up is protecting when malfunction does not run as scheduled. Installation main defense will install a separate relay back up and relay. It's working slower or has delayed over sheets of the main relay when the fault occurred in the electrical system.