System and Network Performance Indicators for the Electricity Generating Authority of Thailand: Current and Future Ones

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ABSTRACT

This paper presents current and future System and Network Performance Indicators/Indices for the Electricity Generating Authority of Thailand (EGAT). Future System Performance Indicators are proposed based on time scale of operation, which is divided into four key processes, namely operation planning, scheduling, real-time operation and after-the-fact processes. Current System and Equipment Indicators used in EGAT and many utilities are also summarized. These indicators may be used to benchmark power system performance with those of other international countries through various transmission system operator/utility groups such as Greater Mekong Subregion (GMS), Heads of ASEAN Power Utilities/Authorities (HAPUA), Transmission System Operator (TSO), etc. Performance Indicators may also be used to improve power system standard and quality of electricity supply in Thailand.

1. INTRODUCTION

System and network performance standard are important issues in modern power system as they ensure the efficient and secure functioning of the power system and appropriate quality of electricity supply [1]. Recently, the power system performance indicators have been used in most of utilities/Transmission System Operators (TSO) [2]-[3]. Moreover, they are also used as a tool to compare or benchmark the power system performance among TSOs/utilities. This can be seen from various TSO/utility groups gathering to improve their power system performance by benchmarking performance parameters among member countries. Transmission System Operator (TSO) group, Head of ASEAN Power Utilities/Authorities (HAPUA)-working group number 2, Greater Mekong Subregion (GMS) Planning working groups are

examples of those, who aim to find power system standard as well as to benchmark the power system performance among the participating countries.

EGAT, only utility responsible for high voltage grid and generation in Thailand, has been measured the system performance by using five performance indicators, namely System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), System Minutes, voltage and frequency deviation [4]. Equipment performance of Transmission lines and transformers are measured by Availability Factor indices. These performance indicators, however, have been used for many years and they have not been revised for almost a decade. Moreover, power system performance is one of important issues for measuring efficient in modern power system and they are required for benchmarking power system parameters with other countries. More performance indicators are required for benchmarking process.

According to the above, attention is drawn in this paper to present current and future system and equipment performance indices that should be used in Thailand. The system performance parameters of Electricity Generating Authority of Thailand (EGAT) are proposed based on time scale operational processes, namely operation planning, scheduling, real-time operation and after-the-fact processes. These indicators are important in finding the power system standard especially for GMS and ASEAN interconnection. They may also be used for benchmarking power system performance with those of other international countries in various transmission system operator/utility groups such as Greater Mekong Subregion (GMS), Heads of ASEAN Power Utilities/Authorities (HAPUA), Transmission System Operator (TSO), etc. Moreover, with the better performance of the system, the quality of electricity supply in Thailand may be improved.

This paper is structured as follows. Section 2 presents current system and equipment performance indices available in various utilities including EGAT, TNB, TSO member countries, etc. Section 3 summarizes the Benchmarking process and input/output parameters used for benchmarking model. Current performance parameters along with the proposed future performance parameters of EGAT are presented in Section 4. Main conclusion of the paper is given in Section 5.

2. POWER SYSTEM PERFORMANCE PARAMETERS

Power system performance is an important issue in modern power system as it reveals efficiency of utility to manage power system in an appropriate way. There are two type of performance: system performance and equipment performance. System performance considers power system by looking at various indicators regarding to the quality of electricity. SAIFI, SAIDI, system minute and voltage/frequency variation are the major system performance parameters used by many utilities around the globe. EGAT also uses these parameters as well as Availability Factor indices to measure equipment performance of transformers and transmission lines. The following subtopics summarize system and equipment performance indicators used by many electric power utilities.

2.1. System Performance

a) System Average Interruption Frequency Index (SAIFI)

SAIFI measures the average number of times of sustained interruptions per delivery point. Sustained interruption is defined as any interruption that last for more than one minute. Delivery point is defined as the point where the energy from EGAT is transferred to MEA/PEA and/or bulk supply customer. It can be computed by using the following equation.

$$SAIFI = \frac{Total\ Number\ of\ Sustained\ Interruptions}{Total\ Number\ of\ Delivery\ points} \quad (1)$$

b) System Average Interruption Duration Index (SAIDI)

SAIDI indicates the total duration of interruption for the average delivery points during a predefined period of time. It is commonly measured in minutes or hours of interruption. Mathematically, this is given in Equation (2).

$$SAIDI = \frac{Sum\ of\ all\ Interruption\ Durations}{Total\ Number\ of\ Delivery\ Points} \quad (2)$$

c) System Minute

System minute or Delivery Point Unavailability Index (DPUI) is the unreliability index to relatively measure energy not served to customers, in terms of duration of total system wide blackout. One system minute indicates an equivalent of total system interruption, with the magnitude of annual system peak, for one minute. Equation (3) show mathematics equation used to compute System Minute.

$$System\ Minute = \frac{Sum\ of\ Unsupplied\ Energy\left(MW-min\right)}{System\ Peak\ Load\left(MW\right)} \tag{3}$$

d) Frequency Deviation (FD)

Frequency variation is the deviation of frequency beyond a certain range. EGAT use $\pm$ 0.225 Hz range for measuring frequency deviation. If the frequency is beyond this range, frequency deviation index is increased. Sampling time of 10 second is used for the calculation.

e) Voltage Deviation (VD)

Voltage variation is the deviation of voltage in a certain range. Normally, 5% of voltage variation is used. In EGAT, VD index is increased if the voltage is out of the 5% voltage range. Sampling time of 10 second is again used for the calculation.

f) Transmission Losses

Transmission losses depend on the square of power transmitted and thus it increases with the power flow on the line. The definition of the transmission losses is defined as

$$\%\ Transmission\ Losses = \frac{\sum E_G - \sum E_T}{\sum E_G} \times 100 \quad \% \tag{4}$$

where $\sum E_G$ is total energy generated into Transmission Network (e.g. own generation, IPP, Co-Gen, Inter-connection Import, Import from Distributed Generation) and $\sum E_T$ is the total energy consumed by transmission network (e.g. Main Intake, HV Sales, Interconnection Export, Power Station uses from grid).

2.2. Equipment Performance

Transformer, transmission lines, protection system and network performance are important issues in the equipment standard. The following subsections explains each index in details.

a) Transformer Performance

- Availability Factor (AF)

  Availability Factor is used to find probability index of services of the transformer. It is defined as available time of equipment in percent during a certain period. Unavailability Factor (UF) can be computed by 1 less AF.

- Transformer Tripping due to Associate Failure

  Transformer Tripping due to Associate Failure considers number of transformers that were automatically tripped or forced out due to defects or anomalies (both electrical and mechanical) on the transformer and on its ancillary components during normal service/operating conditions. The number of tripping is recorded and used as input to compute the transformer tripping index.

- Transformer Tripping due to External Faults or Other Clauses

  Transformer Tripping due to External Faults or Other Clauses considers number of transformer that were automatically tripped or forced out due to other component failure that are not a direct consequence of the transformer component failure itself. The number of tripping is recorded and used as input to compute the transformer tripping index.

- Transformer Age Profile

  Transformer Age Profile considers number of in-service transformers by their age profile and voltage level classification. Transformer age profile may affect the performance of the transformer in long run.

b) Transmission Line Performance

- Availability Factor (AF)

Availability Factor is used to find probability index for the transformer. It is defined as available time in percent of equipment during a certain period. UF can be computed by 1 less AF.

- Transmission Line Tripping due to Associate Failure

  Transmission Line Tripping due to Associate Failure considers number of lines that were automatically tripped or forced out due to defects or anomalies (both electrical and mechanical) on the conductor and on its ancillary components during normal service/operating conditions.

- Transmission Line Tripping due to External Faults or Other Clauses

  Transmission Line Tripping due to External Faults or Other Clauses considers number of lines that were automatically tripped or forced out due to other component failure that are not a direct consequence of the transmission line component failure itself.

- Transmission Line Age Profile

  Transmission Line Age Profile considers number of in-service transmission lines circuit-kilometers (cct-km) by their age profile and voltage level classification.

c) Protection System Performance

- Number of Mis-Operations

  Protection system mis-operation is defined as the incorrect, unwanted and deviation in operation of protective devices and schemes from its intended engineering design principles, philosophies and policies. Protection mis-operation index is defined as

$$\%\ Protection\ Mis-Operation = \frac{MO}{CO+MO} \times 100 \quad \% \tag{5}$$

  where MO is number of CBs that failed to trip and isolate the fault within the designed protective scheme coverage. It includes failure to trip, slow trip, unwanted trip, mal-operation, human error and failure

d) Network Performance

- Network Performance Index

Network Performance Index captures the frequency and susceptibility of the transmission network to faults, unwanted or unplanned tripping (forced outages), as well as the effectiveness of the protections system to isolate the incidences efficiently. The intention of this measure is to evaluate effectiveness of maintenance practices to mitigate faults, failures, and recurring incidences. The index is defined as

$$Network\ Performance\ Index = \frac{Total\ CB\ Installed - Total\ CB\ Tripped}{Total\ CB\ Installed} \times 100 \quad \% \quad (6)$$

This indicator measures the performance of all equipment available in transmission network.

– Unavailability Index

Unavailability Index captures the average duration taken to restore per tripped/failed equipment back to its energized state (fully restored). The intention of this measure is to evaluate efficiency and responsiveness of maintenance personnel in restoring the failed equipment.

3. BENCHMARKING AND COSTS

3.1 Benchmarking

Benchmarking is the process of identifying "best practice" in relation to both products and the processes by which those products are created and delivered. The objective of benchmarking is to understand and evaluate the current position of a business or organization in relation to "best practice" and to identify areas and means of performance improvement. When the lessons learnt from a benchmarking exercise are applied appropriately, they facilitate improved performance in critical functions within an organization or in key areas of the business environment.

Benchmarking is used in power system in TSO/utility level for many years. This can be observed from many utility/system operator groups such as TSO, HAPUA, etc, established to benchmark performance indices. The parameters that have always been considered in the benchmarking process are performance indices and total costs (as well as the number of staff). Cost is considered as the input factor of benchmark model while performance index is the output factor. Each performance index is plotted versus cost for all

member utilities. Performance of utilities can be identified from the location in the graph based on regions of good, fair and poor performance, as they used to specify the performance.

Since the total cost and number of staff are used input for benchmark model, the following subtopics present associated cost including Operation and Maintenance (O&M) cost , Capital cost as well as number of staff.

3.2 Total Costs

a) O&M Operating Expenditure (OPEX)

OPEX is the costs incurred that are directly related to the well-being, security, integrity, reliability and availability of equipment and installations. Technical labor/manpower costs, material cost, spares and vehicle costs associated with normal or day today operation and maintenance activities as well as preventive and corrective maintenance activities are also included.

b) O&M Capital Expenditure (CAPEX)

CAPEX is the costs incurred in refurbishing, replacing and procuring spare equipment as well as purchases of technical tools and equipment are to be included. Cost of vehicles procured is also be included.

c) Others

This type of cost may include insurance cost, asset depreciation cost, expenses for outsourcing/external works, etc.

3.3 Number of Staff

Number of staff may be used as one of the input for benchmark model. It can be used when the OPEX and CAPEX are not available.

4. PROPOSED PERFORMANCE PARAMETERS FOR EGAT

System and performance indicators of EGAT are proposed based on TSO and HAPUA groups. The following sections provide information of system and equipment performance indices.

4.1 System Performance Indicators

The system performance indices are proposed for EGAT based on 4 operation processes and 1 support process. System operation may be divided into 4 different processes based on time scale of operation, namely operation planning, scheduling, real-time operation and after the fact. One may consider the support to be supplement process. Figure 1 shows these four processes of operation as well as the support process. Details of each process are summarized in the follow subtopics

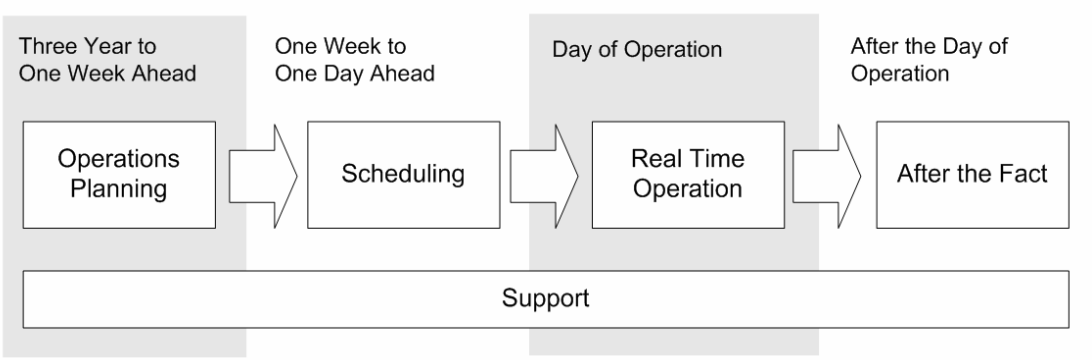

Figure 1: Four processes of operation.

a) Operation Planning

Operation planning is the long term planning that plan outages from roughly three years up to one week ahead. This includes co-ordination and planning outages of generators and transmission. The results is a planning that is one of the inputs of scheduling process. The objective of operation planning process is to produce accurate and timely plans for the scheduling and Real Time operation process.

b) Scheduling

Scheduling is the short term planning cycle to prepare for real time operation. One of the inputs is the outage plans resulting from the Operation Planning process. The scheduling cycle is carried out between one week and one-day head of operation. The objective of scheduling is to prepare an accurate schedule of generating unit dispatch targets to meet the forecasted demand, without violating the planned network capacity, by delivering a balanced and secure power system to the real time operation process.

c) Real Time Operation

Real time operation covers all activities required to operate the generation and transmission system in real time keeping energy in balance. Real time operation is performed through Energy Management System software and the experience of the system operators.

d) After the Fact

After the fact process covers the analysis and reporting of what has happened on the generation and transmission systems. Typically, “After the Fact” activities are taking place after the day of operation. The objective of this process is to provide feedback information on what has happened on the generation and transmission system to enable issues to be resolved.

e) Support

Support covers the activities that enable the operational processes. Dispatcher Training Simulator (DTS) is an example of support process for real time operation.

System performance parameters are proposed based on these five processes. Table I shows system performance parameter proposed for each process. The proposed performance indices may be used as a starting point for the complete performance indicators for EGAT in the future. It can be observed from the Table I that only SAIDI, SAIFI, System Minute, Voltage/Freq. Deviation in the real time operation are currently used for performance indicators of EGAT.

Table I: Proposed System Performance Indictors for EGAT

Process	Performance Indicators
Operation Planning	Number of Planned Transmission Outages
	Number of Planned Generating Units Outages
Scheduling	Accuracy of Peak Load Forecast
	Transmission Congestion: Generation Constrained "ON"
	Scheduled Transmission Outages
	Scheduled Generation Outages
Real Time Operation	SAIDI, SAIFI, System Minute, Voltage/Freq. Deviation
	Load/ Generation Instruction above the Planning (Scheduling)
	Transmission Outages at Distribution Level (MEA/PEA)
After the Fact	Response Time of Area Control Error or Frequency
	Energy Unsupplied due to Incidents
	Unsupplied Energy Incidents
	Transmission Energy at Risk
Support	Operator Training Hours of Teachers (DTS)
	Training Hours Per Operator (DTS)

4.2 Equipment Performance Parameters

Equipment performance indices are proposed for EGAT based on equipment available in the transmission network. Table II shows the proposed equipment performance indictors. From Table II, only Availability Factors of Transformers and Transmission lines are currently available in EGAT.

Table II: Proposed Equipment Performance Indictors for EGAT

Equipment	Performance Indicators
Transformer	Availability Factor
	Number of Tripping
Transmission Line	Availability Factor
	Number of Tripping
Protection System	% Mis-Operation
Overall Network	Network Performance
	Availability Factor

4.3 Total Costs and others

Cost and staff are important input factors in benchmarking process. Table III shows the required input factor for Costs and staff. It is noticed that costs are associated only with transmission system.

Table III: Proposed Performance Indictors for Costs and Others

Type	Performance Indicators
Total Cost	OPEX
	CAPEX
	Other Costs
Staff	Number of Staff

5. CONCLUSION

This paper presents System and Equipment Performance Indices for EGAT based on those used by TSO/HAPUA/GMS benchmarking groups, and various utilities. System performance indices are proposed based on TSO and HAPUW benchmarking groups. They are divided into 5 processes of operation and support. Equipment performance indices are proposed based on the ones used by various utilities. Cost

associated with transmission system and number of staff are important input factors required for benchmarking process.

6. REFERENCES

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