# ESSPI as a Fast Tool for Load Prioritization on Microgrids Design

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***Abstract*—The Energy Storage System Priority Index (ESSPI) was originally presented in the past as a methodology to prioritize load. In this paper, the ESSPI is going to be used as a fast tool for load prioritization in microgrid design. The tool consists of the user inputting the load information based on the classification of the load. The inputs needed are the maximum critical recovery time and the energy consumption of the loads. Loads should be classified into different categories: critical load, essential load, discretionary load, non-essential load, and expendable load. The tool outputs would be the loads arranged based on their priority, the size, and the cost of the microgrid system depending on the user's desired investment for short-, mid-, and long-term investments.**

***Keywords—energy storage, ESSPI, load classification***

## I. INTRODUCTION

This paper uses the Energy Priority Index presented in [1] to create a fast tool for load prioritization on microgrid design. The idea of the tool is to identify and arrange the order of priority of the loads using the index (ESSPI). By doing this now we can also consider those loads for a microgrid design based on the necessity of those loads. The ranking system outlined in this section separates loads into five categories ranging from least important to most important (note: examples presented here are based on the reality of Puerto Rico, it is suggested that the loads be ranked according to the experience for each region/country): Expendable (EXL), Non-Essential (NEL), Discretionary (DL), Essential (EL) and Critical (CL)

The proposed load ranking system is related to the projected time recovery horizon of each load. The Reliability, Resiliency & Recovery Energy Systems (RE3) concept presented in this paper is treated as three kinds/types of investment:

- Short-Term Investment – guarantees a reliable system that includes Critical Loads (CL) and Essential Loads (EL).
- Mid-Term Investment – guarantees a resilient system that includes Discretionary Loads (EL) and Non-Essential Loads (DL).
- Long-Term Investment – guarantees a fully recovered system that includes Expendable Loads (EXL).

The RE3 Segmentation Curve presented in Figure 1 is the expected energy restoration time curve for all loads after a blackout. The idea of the RE3 concept is to minimize the impact of a blackout to society's wellbeing and economy as mentioned before.

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For more information on black start and BESS integration guidelines see "System Restoration from Blackstart Resources" and "Modeling, and Simulations of BPS Connected Battery Energy Storage Systems and Hybrid Power Plants" from the North American Electric Reliability Corporation (NERC), and Order No. 841-845 of the Federal Energy Regulatory Commission (FERC) [2], [3], [4],[5]. per and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

## II. ESSPI EQUATIONS

The equation used for the App presented in this paper comes from the following [1] and is shown below. *Note in this section is not our intention to define or explain each of the meanings of all the variables or how to use the equations. If you desire to know more information read [1].*

1. $t_{(n)}$ – Maximum Critical Recovery Time (*day*).
2. $T_{(n)}$ – Complete Recovery Time (*day*)
3. $CLE_{(n)}$– Critical Load Energy: Total energy needed from loads classified as critical in section 1. Units are in *kilowatt-hours (kWh)*.
4. $ELE_{(n)}$– Essential Load Energy: Total energy needed from loads classified as essential in section 1. Units are in *kilowatt-hours (kWh)*.
5. $DLE_{(n)}$– Discretionary Load Energy: Total energy needed from loads classified as discretionary in section 1. Units are in *kilowatt-hours (kWh)*.
6. $NELE_{(n)}$ – Non-Essential Load Energy: Total energy needed from loads classified as non-essential in section 1. Units are in *kilowatt-hours (kWh)*.
7. $EXLE_{(n)}$– Expendable Load Energy: Total energy needed from loads classified as expendable in section 1. Units are in *kilowatt-hours (kWh)*.
8. $VLE$ – Vital Load Energy: Units are in *kilowatt-hours (kWh)*.

$$VLE = \sum_{n=1}^{i} CLE_{(n)} + \sum_{n=1}^{j} ELE_{(n)} \tag{1}$$

9. $SLE$– Supplementary Load Energy: Units are in *kilowatt-hours (kWh)*.

$$SLE = \sum_{n=1}^{m} DLE_{(n)} + \sum_{n=1}^{k} NELE_{(n)} \quad (2)$$

10. $STESSPI_{(n)}$ – Short-Term Energy Storage Selection Prioritization Index:

$$STESSPI_{(n)} = \frac{CLE_{(n)}}{VLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (4)$$

$$STESSPI_{(n)} = \frac{ELE_{(n)}}{VLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (5)$$

11. $MTESSPI_{(n)}$ – Mid-Term Energy Storage Selection Prioritization Index:

$$MTESSPI_{(n)} = \frac{DLE_{(n)}}{VLE + SLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (6)$$

$$MTESSPI_{(n)} = \frac{NELE_{(n)}}{VLE + SLE}\left(\frac{T_{(n)}}{t_{(n)}}\right) \quad (7)$$

## III. ESSPI Test Case Scenario Culebra, PR

The following ESSPI test case scenario was used [1] and it is going to compare the results obtained from the application in the next section. The data was obtained from NREL report (Contract No. DE-AC36-08GO28308) [6]. The report provides information related to critical and essential loads in this municipality. From the NREL report the following buildings were considered as critical (Table 1) and essential (Table 2). These buildings are the Health Clinic, Wastewater Treatment Plant (WWTP), Municipal Building, Police Station, and Fire Station. For the demonstration of the case study the municipal building will be considered as discretionary (Table 2). The blue color indicates the buildings considered as CL, the green color indicates the buildings considered as EL and the yellow color indicates the buildings considered as DL. The t for the hospital is based on research on how time a hospital can withstand without energy [7]. The other scenarios are estimations based on community feedback and other scenarios are modified for proof of concept of ESSPI [8]. T is presented as a hypothetical case where the service is down for any reason just to prove with different cases for the ESSPI analysis. Table 3 and Table 4 present the inputs and results for the ESSPI analysis.

TABLE 1: BUILDINGS THAT ARE CONSIDERED AS CL.

| Infrastructure Type (Culebra, PR) | Health Clinic | WWTP |
|---|---|---|
| Annual Energy Use (KWh) | 689.622 | 680 |

TABLE 2: BUILDINGS CONSIDERED EL AND DL.

| Infrastructure Type (Culebra, PR) | Police Station | Fire Station | Municipal Building |
|---|---|---|---|
| Annual Energy Use (KWh) | 112.564 | 74.838 | 527.493 |

TABLE 3: ESSPI ANALYSIS FOR SHORT-TERM.

| Infrastructure Type (Culebra, PR) | Health Clinic | WWTP | Police Station | Fire Station |
|---|---|---|---|---|
| t (days) | 3 | 0.25 | 1 | 1 |
| T (days) | 2 | 2 | 1 | 3 |
| STESSPI | 0.2953 | 3.4938 | 0.0723 | 0.1442 |

TABLE 4: ESSPI ANALYSIS FOR MID-TERM

| Infrastructure Type (Culebra, PR) | Municipal Building |
|---|---|
| t (days) | 1 |
| T (days) | 2 |
| MTESSPI | 0.5265 |

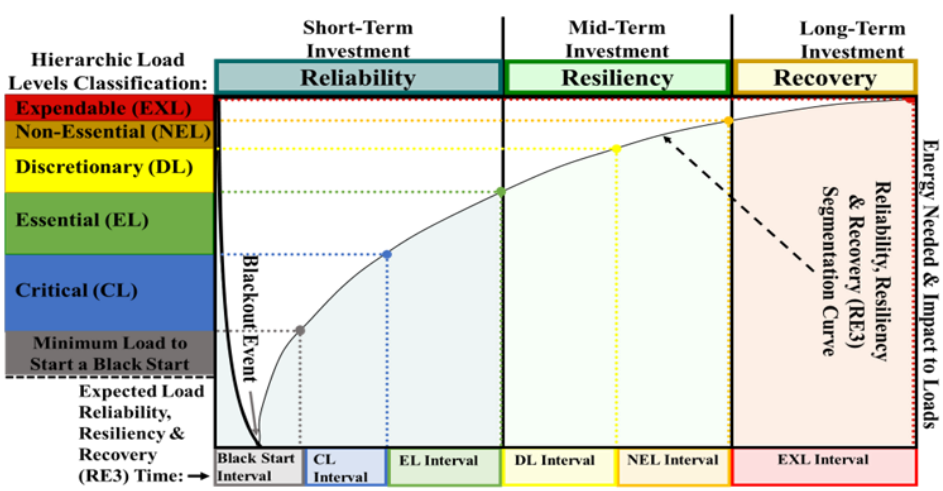


Fig. 1: Proposed Load Reliability, Resiliency & Recovery Load (RE3) Curve. This figure illustrates how should be the RE3 after a blackout.

## IV. ESSPI APP

The program was made with the Java programming language because Java already has its own methods to make a simple and efficient GUI. The program's main objective is to calculate the Short-Term and Mid-Term Energy Storage Selection Prioritization Index. The user can input the ESSPI variables: the maximum critical recovery time, the complete recovery time, the load and that the user specifies the type of energy load. We decided that applying an Object-Oriented approach would be the most efficient design for the program. The program has a public class "Load" that will oversee creating the Load Energy objects with the user inputs. It will also have methods to calculate the individual STESSPI and MTESSPI of each energy load. and the class implements a comparator to be able to compare each load with each other and determine which one is greater. There is also a public class "Calculator" that initializes all the variables needed to update the GUI. In a frame we add buttons, labels, and text fields to make the interface intuitive for the user to enter data. Following equations 1 and 2, there are two methods that calculate the SLE and VLE based on user input. With these methods, the STESSPI and MTESSPI of the energy loads are calculated following the equations 4, 5, 6, 7. Depending on whether it is short or midterm, it is placed in an Array List where it is organized from highest to lowest. To receive data from the user the program uses text fields and buttons. The buttons are also used to display the output and to change the power load class. By pressing the "results" button, we can see the STESSPI and MTESSPI results of the sorted energy loads in order of priority. And then the user can press enter to start again. For cost estimation was used [8] and [9].

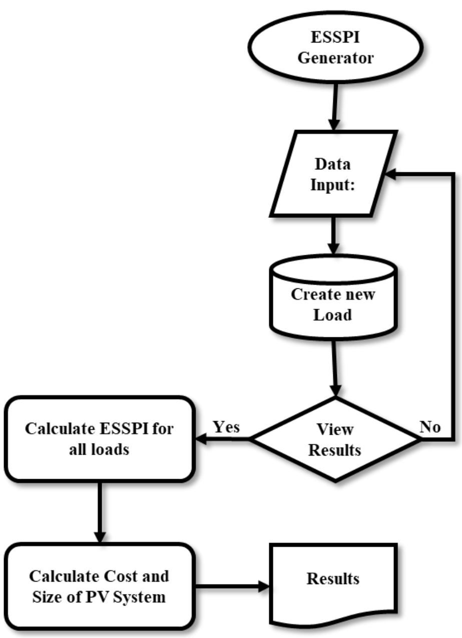


Fig 2. Flow Chart for the app functions. We can see how the user input is used to create loads and then display the ESSPI calculations.

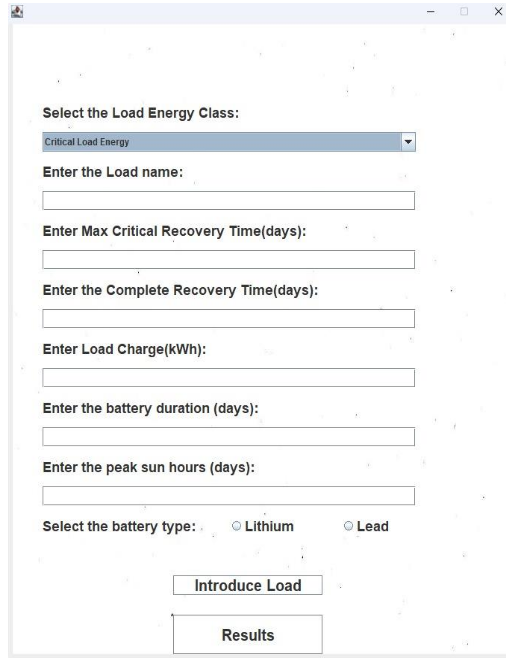


Fig. 3. The interface for the Calculator, here the user creates and saves the load energies.

| | WWTP | Health Clinic | Fire Station | Police Station |
|---|---|---|---|---|
| STESSPI | 3.4938448921689638 | 0.2952735236327029 3 | 0.09612954560299297 | 0.07229433022832853 |
| MTESSPI | 0.0 | 0.0 | 0.0 | 0.0 |
| Size of the batteries(Short-Term) | 5605.28604 | 5605.28604 | 5605.28604 | 5605.28604 |
| Size of the batteries(Mid-Term) | 7608.31524 | 7608.31524 | 7608.31524 | 7608.31524 |
| Cost of the batteries(Short-Term) | $1519032.51684 | $1519032.51684 | $1519032.51684 | $1519032.51684 |
| Cost of the batteries(Mid-Term) | $2061853.43004 | $2061853.43004 | $2061853.43004 | $2061853.43004 |
| Size of the PV System(Short-Term) | 389.25587500000003 | 389.25597500000003 | 389.25597500000003 | 389.25597500000003 |
| Size of the PV System(Mid-Term) | 528.366225 | 528.366226 | 528.366226 | 528.366226 |
| Cost of the PV System(Short-Term) | $291941.98125 | $291941.98125 | $291941.98125 | $291941.98125 |
| Cost of the PV System(Mid-Term) | $396266.41875 | $396266.41875 | $396266.41875 | $396266.41875 |

MTESSPI

Fig. 4. Results, showing the STESSPI and MTESSPI for all the loads from the Culebra Example. The Results are ordered from largest to smallest.

## V. USING THE TEMPLATE

In this Section is presented the different results obtained with the ESSPI application. In Figure 5 are the obtained values of ESSPI at different $T_{(n)}$. In Table 5 are presented the different results obtained for Short- and Mid-term Investment of the: *Size of the batteries, Cost of the batteries , Size of the PV System and Cost of the PV System.* The graph presented in Figures 6 and 7 are the values obtained from Table 5.

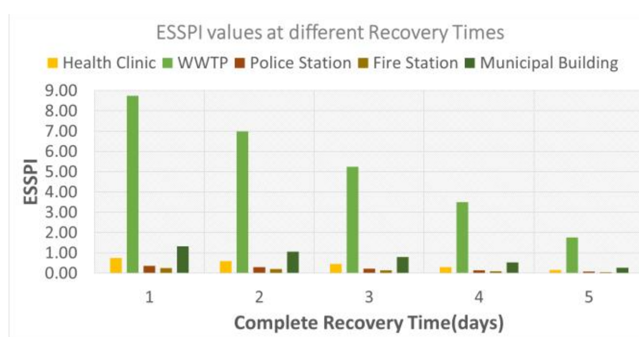


Fig. 5. ESSPI Values at different Recovery Times

TABLE 5: SIZE OF BATTERIES AND PV SYSTEM SIZE WITH COST

| Investment | Size of the batteries(kW) | Cost of the batteries | Size of the PV System(kW) | Cost of the PV System |
|---|---|---|---|---|
| Short-Term | 5605.28 | $1,519,032.50 | 389.25 | $291,940 |
| Mid-Term | 7608.32 | $2,061,853.40 | 528.4 | $396,300 |

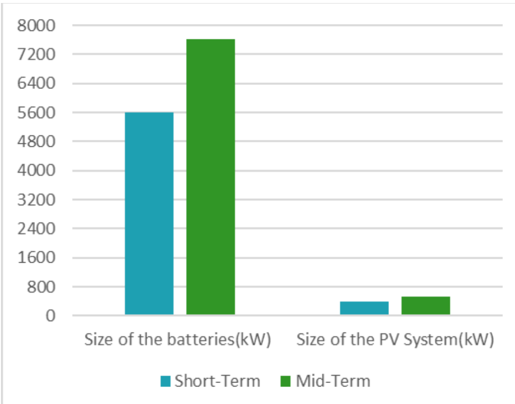


Fig. 6. Comparison graph of system sizes by Term.

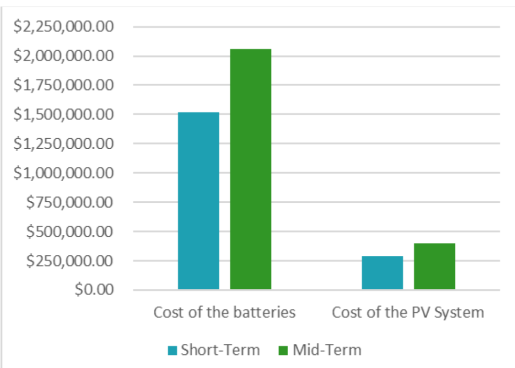


Fig. 7. Comparison of system cost by Term.

## VI. Conclusion

The idea of the tool is to facilitate the identification and prioritization of loads for the user for a microgrid. The user can also obtain other useful information such as the size of the batteries needed to maintain the system and the estimated cost. As well as the size of the PV system and its cost. Then based on that information, the next objective of the tool is to suggest to the user, in a fast way, the size of the system needed to satisfy the energy and power requirements of those loads. Also, sizes and systems cost may vary depending on if the user wants the analysis for short-, mid-, and long-term investment.

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