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ENERGY STORAGE SYSTEM AND CVAR MINIMIZATION IN MICROGRID OPERATION UNDER UNCERTAINTIES CONSIDERING

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Abstract- This article intends to provide a comprehensive two-stage programming based on risk management. As it emphasizes on the power of the online distribution network for distributed energy sources and energy storage systems. To protect the tidal function of the microgrid at any time at the right time for islanding. In fact, the proposed model limits, considering the beneficial island time schedule, the possible solutions of common planning problems to a set of solutions that are able to repatriate the power of the network with existing resources from the micro grid. The complex algorithms that make up wind power generation, wind turbines, and real-time market are the uncertainties that are being considered here. The complete problem is formed as a random-based risk-based planning, scenario-shaped, cross-linear programming, and solved by the CPLEX method. Finally, the effectiveness of the proposed method in a sample system has been implemented through some case studies.

Keywords: Stochastic Programming, Islanding, Risk, Microgrid, Energy Storage.

I. INTRODUCTION

Renewable energy sources, which are almost unpredictable and sequential in nature, can create meaningful work in an active distribution network. In this case, one of the optimal methods for modifying the flexibility of the distribution device and maintaining the balance between consumption and production, must be used by the microgrid.

Microgrid is an example of a small and acceptable low-to-moderate power system with distributed energy resources (DERs), power storage systems (ESSs) and adjustable loads [1, 2]. Therefore, microgrid can produce, transmit, distribute and store power. They can also behave like a local load or local production unit from the point of view of the grid (grid above) [3]. The methods are connected to the network and the quality of the two modes of microgrid operation.

In other words, the microgrid owner minimizes the cost of the operation This is where microgrid and its production units belong to a non-profit distribution company. In tidal mode, microgrid must have sufficient capacity to meet consumer demand. This is if the micro-grid should provide consumers with consumer safety in comparison to economic performance. In this case, loading operations will only be made using the suggestions of the owners of distributed energy resources the tidal process can be selected or after an aberration of voltage fluctuations and faults, which will be possible on the main network. Switching between two microgrid operating modes can be done using the switches installed at the common connect point (PCC) [4, 5]. A major microgrid controller (MMC) must control and optimize the microgrid. [6]. There are many definitive methods for microgrid operational planning. Many studies have been done to solve the microgrid production planning question [7, 8] A lot of research has been done in this article.

Optimization of microgrid probabilities has been studied in [9, 10] due to the lack of definition of wind and sun and regardless of tidal capability and safety. Contributions and operations by authors should be optimized simultaneously and the neural networks used in 9 should be developed.

A kind of solar energy forecast has been proposed in the absence of storage capacity in order to plan for the proper production of microgrid in the market yesterday [10]. A randomized operational planning approach proposed in [11] has been used to determine the hourly reserve capacity to overcome the manufacturing error. In [12], authors proposed a probabilistic prediction strategy for microgrid programming, regardless of micro-drag security restrictions. A two-stage randomized optimization in [6] to accept the uncertainty of renewable energy sources in the prior microgrid security

Again, the energy management of microgrid is proposed mathematically in [13], regardless of the independent days and in real time Market. However, there is no state. A great deal of research has been done in the field of microgrid analysis capabilities similar to that of microgrid randomization. In [14], a duality approach is used to optimize the ability of the microgrid to be automated in the stand-alone mode.

This approach was conducted considering the probability of some tidal scenarios. Interoperability is achieved through a comprehensive two-layer planning in [15]. These layers are called program layer and deployment layer respectively. An additional reserve capacity in the application layer is based on the data of the day if the storage capacity in the upload layer is allocated based on real-time data. Using Microgrid on the islands in [16] and [17] is done using demand management and the use of energy storage systems. In [18], the author developed an updated paradigm for the functioning of the microgrid tide without specifying uncertainty This paper presents a two-stage randomized framework for microgrid optimal planning, which addresses islanding issues and risk constraints, in light of the current and growing profitability of microgrid and the need for reliable and economical operations. The goal is to minimize the cost of operations during a 24-hour horizon. The island's ability to analyze the island is considered as a reference criterion for analyzing the performance of the flexibility mode.

It also examines the distributed roles and distributed energies and energy storage systems. Some of the basics of tidal operations and the representation of uncertainty are in the second part. The proposed approach and its framework are presented in the third section. In Section 4, the objective function and related restrictions are described. In sections V and VI, studies have been done and presented in sequence.

II. ISLANDING AND UNCERTAINTY REPRESENTATION

A. Microgrid and Islanding Operation

Intentional islands or unintentional isles are the preferred feature of the microgrid. This useful feature makes the microgrid work independently, if there is a possible possibility on the main network. In addition, this ability plays a very important role in straw Cost of operations, increasing social welfare and reliability. Due to the intermittent nature of renewable energy sources and the cost of installing more than other types, microgrid developers use dispatchable units such as gas turbines and diesel generators in production scheduling. In addition, the microgrid operation requires minimum installed capacity, which should be at least equal to the maximum microgrid value.

B. Uncertainty Determination

A phenomenon that depends on estimation and prediction and is associated with uncertainty. For example, MMC faces uncertainties such as energy prices, demand for load, and renewable resources. The method used in this paper is uncertainty based on scenarios Two sets of 1000 separate scenarios for both wind energy and real-time energy prices are based on historical data, using a moderate method and Autoregressive Average-Moving (ARMA).

The ARMA model expresses future values of a parameter as a linear function of past values and noise [19]. The higher the number of scenarios generated, the better the optimization accuracy is. Because operating difficulties are complex and the performance of an approach is directly related to its calculation time, the probability gap reduction method is used to reduce the number of scenarios generated. The number of wind and real-time scenarios will be reduced to 10 and 4, respectively Since energy and energy costs are not related, a set of 40 scenarios is planned for each time interval.

Obviously, selecting the right number of scenarios is an agreement between the current time accuracy and the computational hardware performance. More details of the principles of random planning are available in [20].

III. PROPOSED STOCHASTIC FRAMEWORK

The proposed framework for planning randomized security restrictions is shown in Figure 1. The three main parts of this method are input data, microgrid programming and optimal outputs.

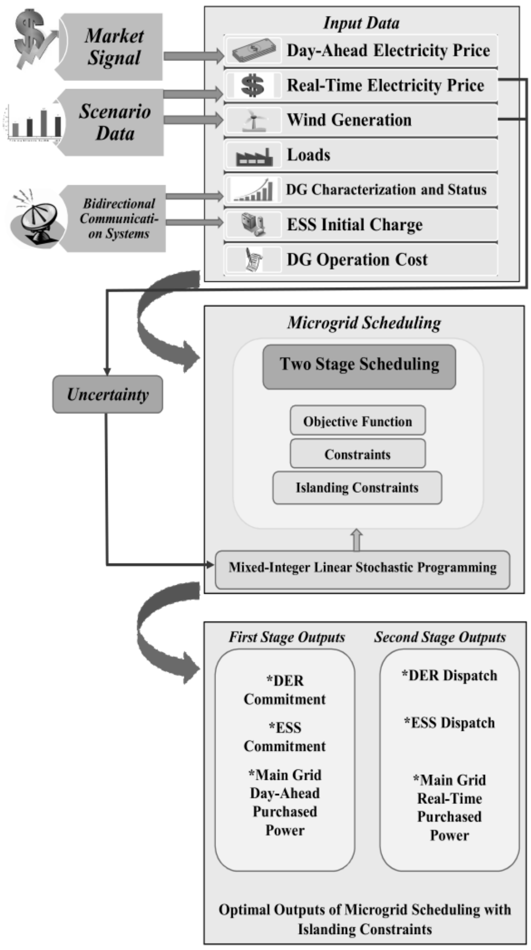

Figure 1. The proposed framework

A. Input Data for Scheduling

Input data is required for optimal planning issues, market signals, operational and economic characteristics of the DER, hourly generated micro-grid hourly-generated scenarios. As discussed earlier, this paper focuses on uncertainty regarding wind power generation and real-time energy prices. Estimated values are derived from historical data.

B. Microgrid Scheduling System

The MMC will make microgrid's proper planning according to its economic and security considerations. In addition to deciding to choose operating mode (connected network or stand-alone mode), MMC also specifies the amount of power exchange between DERs and the network. The proper planning by the MMC significantly differs from the single commitment of power systems. Differences arise from the level of penetration of renewable energy sources, storage capacity, and so on.

Consequently, due to the proximity of DERs and loads, the transmission line probabilities do not appear to be a security measure [18]. In this paper, organizing capabilities are considered as a new security component. The main idea behind this study is that it is most likely to eliminate the main network as compared to other components of a microgrid. The ability to make islanding using additional storage limits for the problem will make sure I remember. Given the uncertainty expressed, the proposed decision-making framework is based on two stages of random planning.

C. Optimal Output Variables

The decision variable of the first stage does not depend on scenarios. DER obligations, ESS charging or evacuation requirements, and pre-sales on the day before the main network, are outputs from the first stage, and these pre-existing decisions are made from randomized operations. The real-time decision variables depend on the realization of the scenarios in the second stage and are determined after the random process. These decisions make DERs output, ESS dispatch, and real-time power purchases of the main network

IV. PROBLEM FORMULATION

In this section, the subject is taken as an integer linear programming (MILP). The objective function and its constraints are described below. As stated above, the target function is defined as minimizing the cost of the entire microgrid operation. The full list of symbols used in the attachment is available

Objective Function:

$$\min \sum_{s\in\omega} prob(s).\left[[\sum_{t\in T}\sum_{g\in G} F(P_{g,t,s})X_{g,t}] + [\sum_{t\in T}\rho_{t,s}^{RT} P_{M,t,s}^{RT}] \right] + \quad (1)$$
$$+\sum_{t\in T}\rho_t^{DA} P_{M,t}^{DA}$$

The first factor in target performance is the operating costs of DERs. The DER cost function is usually represented by a quadratic curve that can be linearly linear. The shutdown cost and startup costs are ignored because they are generally less valuable. The second term in the target function refers to the cost of energy purchased from the main network in the real-time market. Finally, the last term of the cost of energy purchased in the market ahead shows that is not dependent on the scenario.

B. Constraints

The problem constraints are given below:

B.1 Power Balance

The total power generated by the DERs and the power purchased from the main network on the previous day and in real time should be included in total load.

$$\sum_{g\in G} P_{g,t,s} + \sum_{b\in ESS} P_{b,t,s} + \sum_{g\in W} P_{g,t,s} + P_{M,t,s}^{RT} + P_{M,t}^{DA} = P_d \quad (2)$$
$$\forall t\in T, \forall s\in\omega$$

B.2 Main Grid Power Transfer

The amount of power exchanged with the main network is limited because the flow is a limitation line.

$$P_M^{RT,\min} \le P_{M,t,s}^{RT} \le P_M^{RT,max}; \forall t\in T, \forall s\in\omega \quad (3)$$

$$P_M^{DA,\min} \le P_{M,t}^{DA} \le P_M^{DA,max}; \forall t\in T \quad (4)$$

B.3 DER Units Generation Limits

The production and capacity of the expansion store are limited to the minimum and maximum limits.

$$P_g^{\min} X_{g,t} \le P_{g,t,s}\ ;\ \forall t\in T, \forall s\in\omega, \forall g\in G \quad (5)$$

$$P_{g,t,s} + R_{g,t,s} \le P_g^{\max} X_{g,t}\ ;\ \forall t\in T, \forall s\in\omega, \forall g\in G \quad (6)$$

B.4 Ramp-up and Ramp-down Limits

$$(P_{g,t,s} + R_{g,t,s}) - (P_{g,(t-1),s} + R_{g,(t-1),s}) \le RU_g \quad (7)$$

$$(P_{g,(t-1),s} + R_{g,(t-1),s}) - (P_{g,t,s} + R_{g,t,s}) \le RD_g \quad (8)$$
$$\forall t\in T, \forall s\in\omega, \forall g\in G$$

B.5 Minimum Time and Minimum Time

Each of the distributed units is minimized and destroyed as follows:

$$T_{g,t}^{on} \ge UT_g(X_{g,t} - X_{g,(t-1)})\ ; \forall t\in T, \forall g\in G \quad (9)$$

$$T_{g,t}^{off} \ge DT_g(X_{g,(t-1)} - X_{g,t})\ ; \forall t\in T, \forall g\in G \quad (10)$$

B.6 ESS Power and Charge Limits

ESS power is limited to maximum and maximum. Charging, draining and ideal are three different modes that are defined for ESS. Charge mode vb, t is one, when ESS is charged. The discharge mode ub, t is one, when the ESS is drained. ESS is in standby mode if both charging and unloading modes are zero.

One of the modes of charging or discharging is only possible at the same time (15), so the maximum and minimum power constraints are imposed with (11) and (12) Charge the ESS at any time according to the previous charge and the current power (13) is estimated. ESS also includes at least (16) and (17) minimum and maximum time limits.

$$P_{b,t,s} + R_{b,t,s} \le P_b^{dch,\max} u_{b,t} - P_b^{ch,\min} v_{b,t} \quad (11)$$

$$P_{b,t,s} \ge P_b^{dch,\min} u_{b,t} - P_b^{ch,\max} v_{b,t} \quad (12)$$

$$SOC_{b,t,s} = SOC_{b,(t-1),s} - P_{b,t,s} \quad (13)$$

$$0 \le SOC_{b,t,s} \le SOC_b^{\max}; \forall t, \forall s\in\omega, \forall b\in ESS \quad (14)$$

$$u_{b,t} + v_{b,t} \le 1 \quad (15)$$

$$T_{b,t}^{ch} \ge MC_b(u_{b,t} - u_{b,(t-1)}) \quad (16)$$

$$T_{b,t}^{dch} \ge MD_b(v_{b,t} - v_{b,(t-1)}); \forall t\in T, \forall b\in ESS \quad (17)$$

B.7 Risk Constraints

Microgrid operator may be concerned about daily resource planning. Limitations (18)-(20), known as risk constraints, model behavioral risk-taking behavior and risk-taking behavior on tidal status. The left side of equation (18) CVaR as a powerful tool to control the worst effects of the scenario and various uncertainties [21].

$$\frac{1}{(1-\alpha)}\times\sum_{s\in\omega} prob(s)\times\eta_{t,s}-\zeta_t \le \beta\times\{\sum\nolimits_{s\in\omega} prob(s)\times \times(\sum_{g\in G} F(P_{g,t,s})X_{g,t}+\rho_{t,s}^{RT}P_{M,t,s}^{RT})+\rho_{t,s}^{DA}P_{M,t}^{DA}\} \tag{18}$$

$$\sum_{g\in G} F(P_{g,t,s})X_{g,t}+\rho_{t,s}^{RT}P_{M,t,s}^{RT}+\rho_{t,s}^{DA}P_{M,t}^{DA}+\zeta_t-\eta_{t,s}\le 0 \tag{19}$$

$$\eta_{t,s}\ge 0 \tag{20}$$

V. SIMULATION RESULTS

An ordinary microgrid, including four distribution units (two 5-megawatt units and two 3-megawatt units), an ESS with a capacity of 10 megawatts, and a 1-megawatt wind power plant are considered for the proposed method. This problem runs on a 2.2 GHz computer and is solved using CPLEX. The manufacturing units and ESS specifications are shown in Table 1. The predicted values for loading microgrid loads and market prices for the day are shown in the table below. Below, five studies have been conducted and discussed.

A. Optimal Scheduling Without Islanding Capability

The proposed framework is tested without islanded operation mode and risk constraints. The optimization problem is solved over a 24 hours horizon. The commitments results are tabulated in Table 3.

Table 1. DERs characteristics

Gen. Unit	Cost Coefficient ($/MWh)	Min-Max Generation Capacity (MW)	Min Up-Down Time (hour)	Ramp Up-Down Limit (MW/h)
G1	27.7	1-5	3	2.5
G2	39.1	1-5	3	2.5
G3	61.3	0.8-3	1	3
G4	65.6	0.8-3	1	3
ESS	-	0.4-2	5	-
Wind	0	0-1	-	-

Table 2. Hourly load and day-ahead market price

Hour	1	2	3	4	5	6	7	8
Market Price ($/MWh)	27.73	20.97	23.51	25.36	33.51	35.8	37.3	42.83
Load (MW)	10.73	10.54	10.47	11.03	10.79	10.81	12.12	12.93
Hour	9	10	11	12	13	14	15	16
Market Price ($/MWh)	41.84	47.09	57.06	68.95	65.79	66.57	65.44	79.79
Load (MW)	13.19	13.78	14.08	14.13	15.92	17.27	17.36	17.69
Hour	17	18	19	20	21	22	23	24
Market Price ($/MWh)	115.5	110.3	106.05	95.53	77.38	70.95	59.42	56.68
Load (MW)	18.13	18.14	17.56	17.51	16.00	13.03	11.82	11.45

Table 3. ESS and DERs schedule without islanding constraint

Gen. Unit	Hours (1-24)																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
G_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_2	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_3	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0
G_4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0
ESS	-1	-1	-1	-1	-1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0

When the government has a pledge of 1, the unit is in the state and otherwise it is zero. Charging, idling and discharging, they are the ESS commitment status and are displayed respectively with -1, 0 and 1. When the main network power price in the early hours of the planning horizon is low, the ESS is charging and maximizes power from the main network, which is 7 megawatts, which is the same as the previous day, the transmission limit is similar

When the cost of energy is high (even higher than the operating cost of DERs) at peak times, ESS will be discharged at this time. The total expected cost of the operation is $ 12,087.95. The total energy of 80.69 MWh is purchased from the main network and 33.84 MWh is the amount of energy purchased from the real-time market. This figure showed that it seems reasonable for microgrid to participate in the real-time market.

As shown in Figure 2, within a few hours, microgrid will not buy any power from the main network, but, for example, it cannot generally work in this mode during the early hours. These programs are only economically feasible, regardless of the general ability of general microgrid.

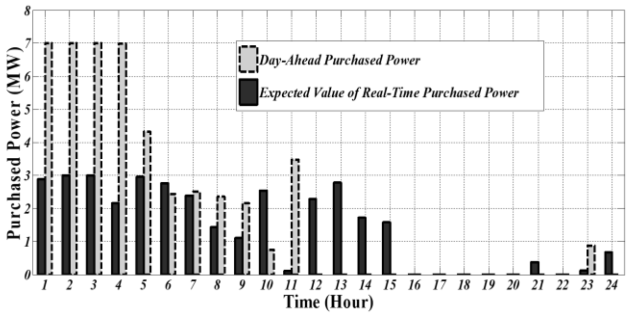

Figure 2. Main grid purchased power without islanding constraint

The output power of the ESS, which is variable in this case, is shown in Figure 3. At the end of the fifth hour, the ESS will be fully charged and will be evacuated between 13-20 hours, the price being as high as in Table 2.

With this unsafe scheduling, if a typical error with a 1 hour repair time in the high current network at t=3 occurs (e.g. the loss of the main network at t=3), the energy will be no more than 10 MWh. In these circumstances, if the loss amount is $ 40 / megawatt hours, then there will be an additional expense that should be added as a penalty to the target's performance. The cost of this penalty will result in a total operating cost of $ 12,487.95. Table 4 shows the details of the function of the target function.

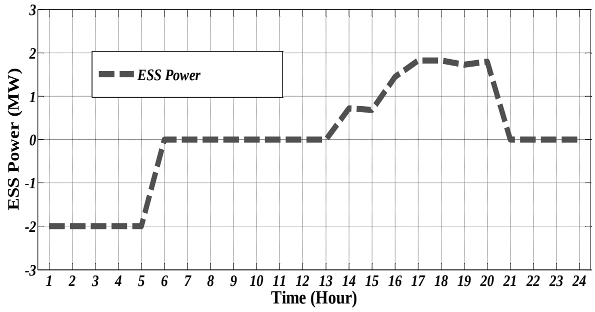

Figure 3. ESS output power - insecure scheduling case

Table 4. Cost of objective function terms

Term	Cost
DERs operation	9396 $
Real-time purchase	1208 $
Day-ahead purchase	1483.95 $
Total	12,087.95 $

B. Security Constrained Scheduling Considering 1 Hour islanding Duration

In these circumstances, it is assumed that the period of non-availability of the network is longer than 1 hour. As shown in Table 5, additional units are committed to be online to provide evaluation, but their operations are not economical. The total amount of energy purchased from the main network will be reduced to 63.48 MWh, and the total cost of the operation will increase to $ 12,435.111. The total cost of the operation (e.g., $ 347.161) is greater than the previous one. This cost can be considered as Asian economic loss.

Table 5. ESS and DERs schedules with τ=1

Gen.	Hours (1-24)																							
Unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
G_1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
G_4	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0
ESS	-1	-1	-1	-1	-1	-1	-1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0

Note that ESS depletion time increases by 11 consecutive hours. This means that the ESS is depleted at a lower rate to maintain the balance of the micro-grid power in the event of a 1 hour cut off of the main grid for all horizons. The changes caused by charging or mixing the ESS between this program and the previous one are shown in Figure 4. Again, the details of the objective function are given in Table 6.

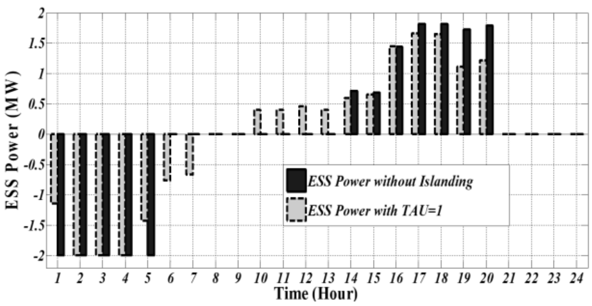

Figure 4. ESS power differences between the secure and insecure scheduling

Table 6. Cost of objective function terms in secure scheduling (τ=1)

Term	Cost
DERs operation	10399 $
Real-time purchase	1028.6 $
Day-ahead purchase	1007.51 $
Total	12,435.111 $

C. Effect of ESS Capacity on Scheduling

In the previous research, ESS is considered to be 10 MWh. To display the effect of storage attributes in planning, ESS is replaced by a quick list with the new features presented in Table 7.

Table 7. New ESS Specification

Gen. Unit	Capacity (MWh)	Min-Max Generation Capacity (MW)	Min Up-Down Time (hour)	Ramp Up-Down Limit (MW/h)
ESS	20	0.2-3	2	-

Table 8. Effects of ESS characteristics on scheduling

Case study	Total cost	Decreased cost
Optimal Scheduling	11,762.596 $	325.354 $
Scheduling with τ=1	12,086.895 $	348.216 $

At the same time, the ESS specification leads to a great deal of cost savings in operating costs, and there must be an agreement between the investment and operating costs. Using the new ESS, a summary of the results is presented in Table 8

D. Effect of Risk Constraints on Islanded Operation

To discuss the effects of hazard limits, CVaR and the expected cost of the expected increase are based on the beta parameter. In fact, when the beta is chosen close to one, it means that the operator tries to plan all the resources to offset the negative economic effects of the worst scenarios. In this case, we named the operator as a dangerous operator. As a result, when the beta is more than one and receives more, the operator plans in a risk-taking manner. Figure 5 illustrates the proposed cost and CVaR behavior based on the beta deviation.

When the beta reaches 1.5, the risk limits are not considered, and the problem is most at risk, regardless of the worst scenes.

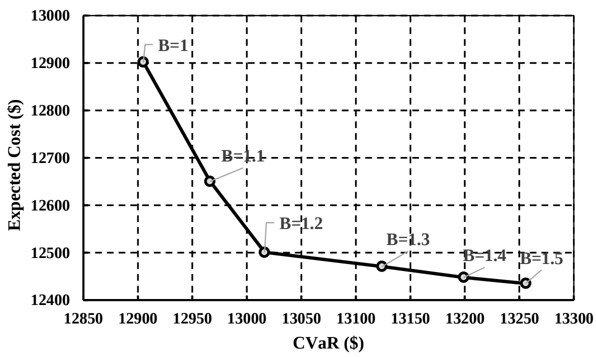

Figure 5. Expected cost versus CVaR trend

VI. CONCLUSIONS

Microgrids, which are the active parts of the distribution network, have a great impact in enhancing reliability, flexibility, and provision of side services infrastructure. A risk-based random framework is proposed in this paper

To plan optimal microgrid energy sources, interrupted scheduling is to demonstrate the benefits of using microgrid in the real-time market, indicating no certainty of wind power generation. Storage capacity is achieved by adding storage capacity to the units and energy storage system. Three risk limits examine operator behavior from risk aversion in tidal operations. Additionally, risk planning makes CVaR less worthwhile, which means that control is admirable in the worst-case scenario.

As a result, the studies show that wind energy savings are compensated for by participating in the real-time market and can use the ESS to change the peak load to the bottom hours of the island's operations. Solved problem using CPLEX based on MILP formula.

NOMENCLATURES

A. Sets

G	Set of dispatchable DGs
ESS	Set of energy storage systems
W	Set of wind generation units
ω	Set of Scenarios

B. Indices

g	Index for DERs
b	Index for ESS
t	Index for time
s	Index for scenarios
d	Index for load
ch	Superscript for ESS charging mode
dch	Superscript for ESS discharging mode
DA	Superscript for day-ahead
RT	Superscript for real-time
α, β	Risk parameters.
ζ_t, $\eta_{t,s}$	Auxiliary variable of risk constraints

C. Parameters

RU, RD	Ramp up and ramp down rate
UT, DT	Minimum up and minimum down-time
MC, MD	Minimum charging and Minimum discharging time
ρ	Market price
$Prob$	Probability of each generated scenarios

D. Decision Variables

X	Commitment state of dispatchable units
P	Output power of DERs
R	Reserve capacity
P	Main grid power
SOC	ESS state of charge
V	ESS charging state of commitment
u	ESS discharging state of commitment
T^{on}, T^{off}	Number of successive on/off hours
T^{ch}, T^{dch}	Number of successive charge/ discharge hours

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