Optimization Strategy Considering Energy Storage Systems to Minimize Energy Production Cost of Power Systems

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Abstract- Using renewable energy by integrating Energy Storage Systems (ESS) can serve to decrease energy production cost of Distributed Generators (DGs) as long as their operation is optimally managed. In this context, this work proposes the optimization of the energy production cost considering a two-level charging strategy for ESSs. For a 24 hours operation cycle, the optimization tries to reduce the total cost by minimizing the quantity of energy to be procured from the Distributed Generators (DGs) at each time period. Additionally, the objective is to determine the quantity of energy surplus generated by Renewable Energy (RE) to be stored in the storage system and determining the using of ESS by applying two levels for proper charging of the battery. The proposed formulation allows simultaneous optimizing DGs and REs, which interact directly when a strong increase in demand is present. In this work, the problem is modeled as a Mixed Integer Linear Programming (MILP) optimization problem. This approach is implemented under the GAMS 24.7.1 environment and is validated by using OSICPLEX. The given model can easily combine different sources of energy (renewables with battery and generators); by organizing the resources with high performance and flexibility. The optimization cost is implemented in a real case and the obtained results confirm the effectiveness of the proposed methodology.

Keywords Renewable energy; energy management; energy storage; mixed integer linear programming (MILP) method; economic scheduling.

1. Introduction

Renewable energies are the most attractive and economic powers due to its smooth production and lower cost, encouraging developed countries to focus on industry consuming a high level of energy among the total of energy produced. Using renewable energy by integrating Storage Systems (ESS) means reducing energy production from the generators and decreases the potential of Distributed Generators (DGs) by removing additional cost and environmental impact expected by the additional plant. However, to have a proper operation of ESSs; they must be integrated into a practical production system [1]. Most research has been focused on wind and solar energy production by using electrical ESS [2]-[3] because of their yields and interesting costs per kW. Storage systems provide a variety of benefits; they can be used to support RE for many aims, sustaining stand-alone generating systems [3], [5], [6], exchanging electricity with the grid [4], overcoming the power quality problems associated to everyday changes in the load and the intermittent nature of the energy produced from RE [7]. The optimization of the utility grid operations is crucial for maintaining the energy resources in a cost-in an economical way [8]. A process for a hybrid system that optimizes the price of energy is presented in [9], is made by using a variety of parameters: components combinations, the orientation of PV modules, rated power, tower height of the wind turbine and the battery capacity. A strategy of power balancing is proposed in [10] by implementing energy management, reducing peak demand, avoiding undesirable power injection in the grid and making full use of solar energy production. The same situation the problem is resolved in [11] using the linear programming method, and minimizing the cost installation in [12], a deterministic model is used with a robust approach.

In this paper, the optimization model has been used as a mixed integer linear programming to minimize the total of primary energy cost and time of charge/discharge of battery which is not used before in literature review. For this reason, the primary task is to establish RE which has to works flexible, continually and economically. Diverse models for optimization have been proposed including linear programming, dynamic programming, heuristic methods and swarm optimization to find the optimal solution. Also, Mixed Integer Linear Programming (MILP) is applied to resolve an economic problem. In literature, MILP is used for optimal power flow [13, 14], transmission planning [15, 16] and optimal transmission switching [17].

A multi-objective evolutionary algorithm and genetic algorithm are used [18] for the optimization tool finding the best combination of the hybrid system. In the same context in [19], a genetic algorithm is applied to optimize the cost and the sizing of the multi-source system. A strategy of energy management for a hybrid system is used [20, 21] to reduce the cost and satisfy the demand. To ensure the pick demand, minimize the cost and preserve the environment, the electrical Energy Storage Systems (ESS) can be used with renewable energy [22- 24]. Moreover, the distributed energy resource systems and the energy storage systems (ESS) are considered an essential technology [25, 26]. To generate power in a limit level of a few kW to a few MW; the DERs are placed at the distribution level [27]. To compensate for the power and provide power supply in cases of instantaneous voltage drop for a distributed energy network the ESS is studied as a key solution in [25, 26]. In addition, to compensate for the instability caused by the constant power load in the micro-grid a hybrid energy storage system is proposed. In addition to that, the hybrid system is composed by battery compensator supplying long-term load demand and ultra-capacitor compensator providing the transient load demand. The hybrid energy storage is implemented using a virtual impedance-based load side compensation technique [28]. Besides, a control strategy for the storage system is used to compensate the intermittent power fluctuations from the hybrid system [29], and controlling active power, building management system an optimization technique is proposed [30-32]. In [33] a MILP is used as a control method for the regulation of energy storage in grid-connected electricity microgrids. A strategy of energy management is presented in [34] to keep the power balancing between the photovoltaic (PV) and energy storage system. The authors in [35] formulate a case of a hybrid system diesel-wind-PV as a model of linear programming with three objectives: decreasing the total cost, minimizing of CO2, and forming a raised limit on the not intended energy. In [36] the linear programming is implemented to obtain a solution for a combination considering wind- solar-battery and diesel for two real powers except for electrical network systems in India and Colombia. The obtained results of both studies confirm that the combination of resources can be possible. In [37] a model of linear programming is developed for a hybrid system to reduce the total cost, power losses, and decrease of the electricity supply capacity. A methodology with linear programming in [38] for the sizing is used to optimize the cost of hybrid system considering PV-wind battery.

A multi-objective genetic algorithm is proposed in [39] for a hybrid photovoltaic system - wind energy-battery for rendering two goals; annual cost reduction and loss of the probability of supply. The role of Economic Dispatch (ED) is scheduling DER generations with considerations of optimization cost and system restrictions [40]. Besides, implementing Lagrange multipliers can be used to solve Economic Dispatch (ED) problems of diesel power generators [41]. However, using an ESS in Economic Dispatch makes the resolution difficult for its time dependency [42]. ED problems are solved using a variety of techniques such as dynamic programming [43], linear programming [44, 45].

In brief, our contributions are; 1) Construction of a model considering a formalized modeling approach, which is suitable to be employed in the optimization of energy production; 2) Formulation of an objective function for minimizing the DGs running costs; 3) Economic scheduling for DGs;4) Validation results confirming the using of the advanced strategy.

The proposed formulation model focused on: 1) Optimization of the production cost of DGs; 2) then deciding which type of energy should meet the load at a minimum cost; 3) after that, decide which units are ready to generate the power with a low price (economic dispatch); 4) with the optimization of charge and discharge of the battery; 5) finally, keeping the level of the battery at the start horizon at the same at the end of the day, to be ready in the next day.

In this research, the primary purpose is to meet the energy demand with the cheapest cost. We are concentrating on determining the proper organization of multiple sources of the system. Considering economic aspects are also essential to assess the final configuration with all components. Therefore, system model, energy analyses, and cost factors are examined in the coming sections.

This work develops the previous study presented in [46] by; i) examining experimental results; ii) including additional simulation results, and iii) considering the costs of the power exchanged with storage systems.

Before starting this work, energy management, forecasting production and demand have been studied in [47-49]. The EMS decides generators, renewables, and energy storage usage, considering the future consumption based on several defined costs objectives. A MILP multi-objective optimization method is adopted for forming energy management decisions to obtain the best optimal solution with multiple targets in the operation of the network systems. Using an integer variable in this method benefits to take into consideration charging/discharging inefficiencies, the proposed strategy has various aspects compared to previous related work in the literature such as [34-39]. A novel form of the cost objective reflects micro grid power demand shaping objectives, generators operation costs, and time of charging and discharging.

This paper is composed as follow: 1) Electrical Network Description in Section II; 2) Hybrid System Models are then described in Section III; 3) Result and Discussion in Sections IV is given, and 4) eventually, conclusions are illustrated in Section V.

2. Electrical Network Description

Renewable energies (wind and solar) have the interest in being an unlimited resource, they preserve the environment. However, they have a technical disadvantage, and they are much less controllable since their primary energy cannot be controlled. Therefore, the insertion of renewables into the electrical network poses technical and economic challenges. The grid is designed using the traditional and renewables production, systems of transport and distribution. The energy is transported and delivered through electrical networks (transmission and distribution networks which differ using the voltage level). The solar power and storage systems demand inverters to convert from direct current (DC) to alternating current (AC) before supplying load through the control system. A representation of the electrical network is provided in Fig.1.

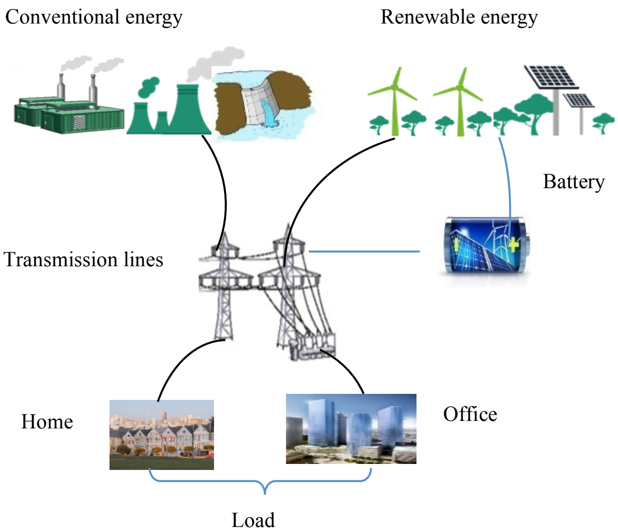

Fig. 1. Description of the electrical network.

When the output power of the RE sources exceeds the load, the battery charged. However, if the amount of energy in the battery reaches the maximum allowed level while the wind and solar together still passes the load, the excessive power should be exported to a dummy load. Meanwhile, whenever the power of the wind generating system and solar energy is below than the load, the battery will be discharged. In this study, the generators are taken to be a unique system where the wind and solar energy cannot ensure the demand at the same time.

2.1. Data Collection

In this section, the input data assessed for one day (24h) is collected to be used in order to test the system. Renewable energy profiles are presented in Fig.2, Fig.3, and load consumption profile is shown in Fig.4.

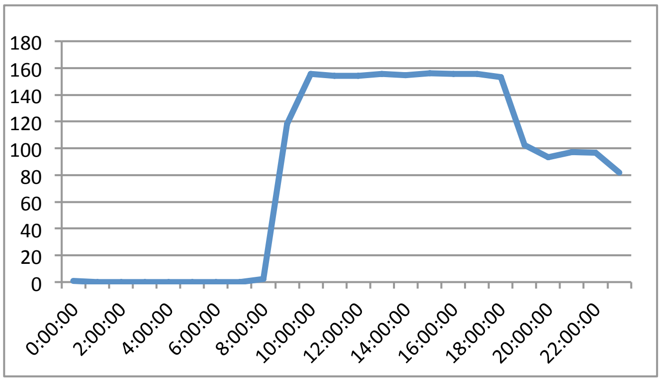

Fig. 2. Hourly production by solar energy for one day (kWh).

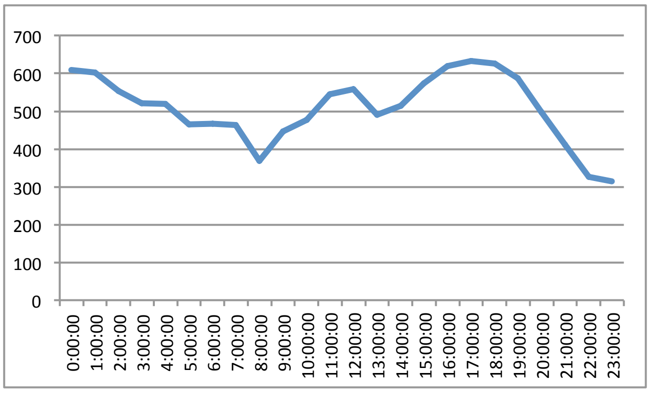

Fig. 3. Hourly production by wind energy for one day (kWh).

According to the graphs shown in "Fig.2" and "Fig.3", the production from wind energy is dominant compared to the solar energy in this case. Over the day, the load is limited by the consumers. The energy consumption has been registered around 600KWh (from 00h until 08h), after that the consumption increase respectively in the middle of the day due to the population movement.

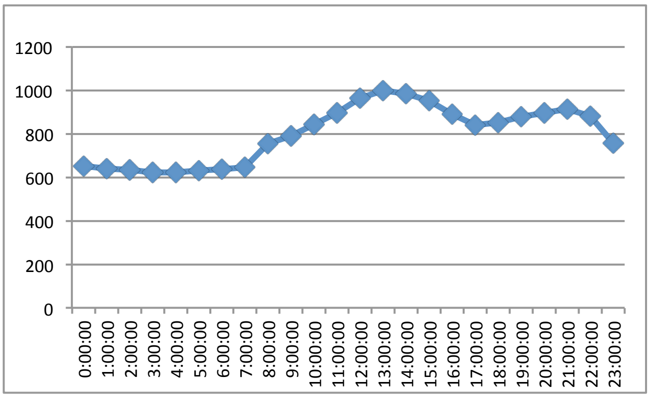

Fig. 4. Hourly load profile for one day (KWh).

3. Submission Process

3.1. Wind turbine model

The wind energy data collected from the weather with values for wind speed, direction, air temperature, and air pressure. In addition, is represented by a statistical distribution characterized by an annual average wind speed value. The energy of a wind generator is given as follows [50]:

$$P_{wg} = C_p * \eta_{gb} * \eta_g * \frac{1}{2} * \rho * A_{wt} * V^3 = \eta_t * \frac{1}{2} * A_{wt} * V^3 \quad (1)$$

With

$\rho[{}^{kg}/_{m^3}]$ =Air density=$\frac{353.049}{T_a} * e^{(-0.034(^Z/_{T_a}))}$ and $\eta_t = C_p * \eta_{gb} * \eta_g * \rho$

The parameters are described below:
Z (m): the elevation and Ta (C), is the temperature;
V (m/s): the wind speed;
A_{wt}(m^2): is the wind turbine swept area;
C_p: The turbine efficiency;
η_{gb}: The gearbox efficiency;
η_g: The generator efficiency.

3.2. PV generator model

The electrical power of a PV generator is given as follows [51]:

$$P_{pv} = \eta_{pv} * A_{pv} * I_r \quad (2)$$

Where η_{pv} is the power conversion efficiency of the module (power output from the system divided by power input from the sun); A_{pv} (m^2): The surface area of PV panels; I_r (W/m^2): The solar radiance. The generator efficiency is given by [52]:

$$\eta_{pv} = \eta_r * \eta_{pc} * [1 - \beta(T_c - NOCT)] \quad (3)$$

With η_r is the reference module efficiency; the efficiency of polycrystalline silicon technology has been used with 13% [53]. η_{pc} is the power conditioning efficiency, is equal to 0.9 with a perfect maximum point tracker [17]. β is the generator efficiency temperature coefficient, ranging from 0.004 to 0.006. T_c is the cell temperature (C). $NOCT$ is the normal operating cell temperature (C) can be calculated when the cells operate under standard operating conditions: irradiance of 800 W/m^2, 20(C) ambient temperature, average wind speed of 1 m/s, module in an electrically open-circuit state, wind oriented parallel to array's plane and all sides of the array fully exposed to wind [54]. A methodology for modeling each component is explained in the next section. The model given in this study is a constrained mixed integer programming that considers discrete time representation with t as the primary unit. The characteristics of power generations from conventional and renewable energy sources are taking into consideration as constraints for this optimization problem. The function representing the production:

$$\sum_{i=1}^{3} \alpha_i P_{i,t} + \sum_{j=1}^{2} \alpha_j P_{\text{res,t}} \begin{cases} \alpha_i = 0 \text{ for } P_{\text{res,t}} \geq P_l \\ \alpha_i = 1 \text{ for } P_{\text{res,t}} < P_l \end{cases} \quad (4)$$

With:

$\alpha_i P_{i,t}$: The quantity of conventional energy produced at time t.

$\alpha_j P_{\text{res,t}}$: The amount of renewable energy generated at time t.

The DG operation decision variable can be estimated based on the wind, PV, battery, power demand, and discharge of the battery, which is given below:

$$\alpha_i = \begin{cases} 0; \text{ if } \sum_{j=1}^{2} P_{res,j} + \sum P_{disch} \geq \sum P_l \\ \sum_{i=1}^{3} P_i + \sum_{j=1}^{2} P_{res,j} + \sum P_{disch} \quad \text{, otherwise} \end{cases} \quad (5)$$

In addition, this function enables defining the quantity of produced energy. In addition, to obtain a balance among the different sources to meet the needs of customers.

Objective function:

$$\text{Min} \quad Z = \sum_{i=1}^{3} P_{i,t} \times C_{i,t} \quad (6)$$

Subject to:

$$\sum_{i=1}^{3} A_{i,t} * P_{i,t} + (1 - B_t) * P_{disch,t} - B_t * P_{ch,t} + \sum_{j=1}^{2} P_{res,t} = P_{l,t} \quad (7)$$

$$P_{min} * A_{i,t} \leq P_i \leq P_{max} * A_{i,t} \quad (8)$$

$$P_{res} \geq Cap_{res} \longleftrightarrow P_{res} = P_{pv} + P_w \quad (9)$$

$$P_i \leq Cap_i \quad (10)$$

$$(1 - B_t) + B_t = 1 \quad \forall t \in T \quad (11)$$

$$0 \leq P_{ch,t}^{bat} \leq B_t * P_{ch.max,t}^{bat} \quad B_t \in \{0,1\} \ \forall t \in T \quad (12)$$

$$0 \leq P_{dis,t}^{bat} \leq (1 - B_t) * P_{dis.max,t}^{bat} \quad B_t \in \{0,1\} \ \forall t \in T \quad (13)$$

$$ES_t^{bat} = ES_{t-1}^{bat} + P_{ch,t}^{bat} * \eta^{bat,ch} - P_{dis,t}^{bat} / \eta^{bat,dis} \quad (14)$$

$$ES_{min}^{bat} \leq ES_t^{bat} \leq ES_{max}^{bat} \quad (15)$$

$$ES_{t=0}^{bat} = ES_{t=24}^{bat} \quad (16)$$

The linear objective function (6) is considered for optimization cost of generators operation. By studying this linear cost function, the optimization problem represents a mixed integer linear optimization problem. Equation (7) is a power balance constraint for each time. $P_{i,t}$ is a power supply by the generator i at time t. Since only generators have a cost for primary material and costs renewable energies can be neglected. The parameters applied in the suggested formulation is illustrated, respectively (see Table 2), where, for simplicity the subscript i and j when referring to the i^{th} and j^{th} system. The objective function is minimizing the total cost of the generators. Besides, the superscripts max and min indicate the upper and lower generation bounds. Moreover, binary variable B_t is employed to define the status of ESS (charge/discharge). The mathematical formulations representing the combined generation have been proposed in (8), (9) and (10). The binary variable $A_{i,t}$ indicates that if the generators unit is on/off at each time t. The constraints (11)-(16) relates to the ESS. Where $ES_{t=0}^{bat}$ is the energy level at the start of the horizon, and ES_{min}^{bat} , ES_{max}^{bat} are lower and upper bounds, respectively. The energy can be supplied through PV, WIND, ESS and the generators.

3.3. Generation Balance

Total power generation from renewable energies should satisfy load at time periods. The balanced power between generators and renewables is an essential equality constraint of this optimization problem and can be exposed as (7). Also, the energy balance must be held all the time.

Hence,

$$P_l - \sum_{i=1}^{3} P_i - \sum_{j=1}^{2} P_{res} = 0 \qquad (17)$$

Where P_D is the power demand, P_{res} represents the energy production from renewables, and P_i is the output power of unit i^{th} in the system.

3.4. Generation Limits

The energy expected from the generator i^{th} is a value bounded by the minimum and maximum power value at the time t.

$$P_{min,t} \leq P_{i,t} \leq P_{max,t} \qquad (18)$$

The boundary P_{min} and P_{max} are estimated as a function of the time to analyze cases when the available power is variable.

3.5. Generation cost (Fuel cost)

The cost function associated with operating a generator varies according to the output of the generator. The objective function assumed to be a quadratic function may be represented as in form:

$$F_c = \sum_{i=1}^{3} a_i + b_i * P_i + C_i * {P_i}^2 \qquad (19)$$

Where P_i is the output of the generator unit i^{th}, and a_i,b_i, C_i are cost coefficients of unit i^{th}.

3.6. Energy storage system

Energy Storage System (ESS) is used to decrease the inequalities within the production and the demand. Mixed Integer Linear Programming (MILP) is used to optimize charge/discharge of the battery during the transient period and rates of the battery. ESS has a status; is equal to 1 when the ESS is fully-charged and zero otherwise. In (12) and (13) prove the functioning of the power plant, previously included in (7), and besides some conditions in the power value that can be attached to the ESS, respectively. On the other side, restrictions in (14) and (15) are centered on how the SOC of the ESS progress during the day and what the SOC level limits to these variations are. In addition, the charging and discharging efficiency coefficients have been included in (14), to involve a linear behavior of the system. The proposed organizational strategy in Fig.6 aims to minimize the running cost. In addition, provides deducting the quantity of energy needed and the energy which needs to be produced by the available sources. Power demand is an input; the assessment of the power of renewable energy and the power of the ESS is an obligation to verify if the ESS with renewables can ensure the power load or not. One hand, if the renewables with battery are equal to power demand is a routine operation. On the other hand, if the power load is superior or inferior to the renewables with ESS, we should compensate with generators. The purpose of the optimization is to maintain the SOC level as close as possible to a reference value at all times. This permits reducing the cost of energy production from generators.

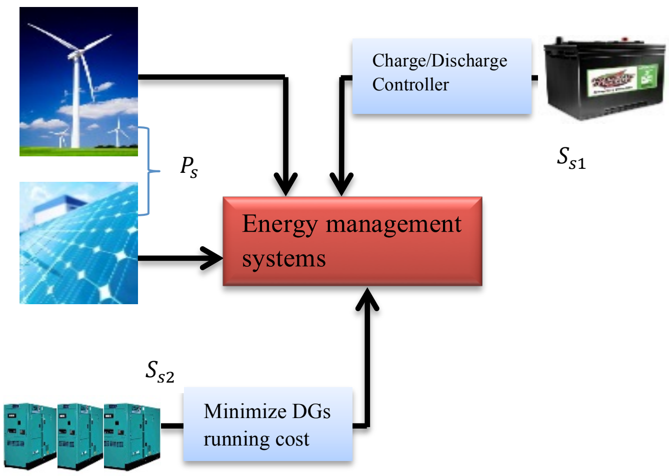

Fig. 5. Block diagram of the proposed strategy.

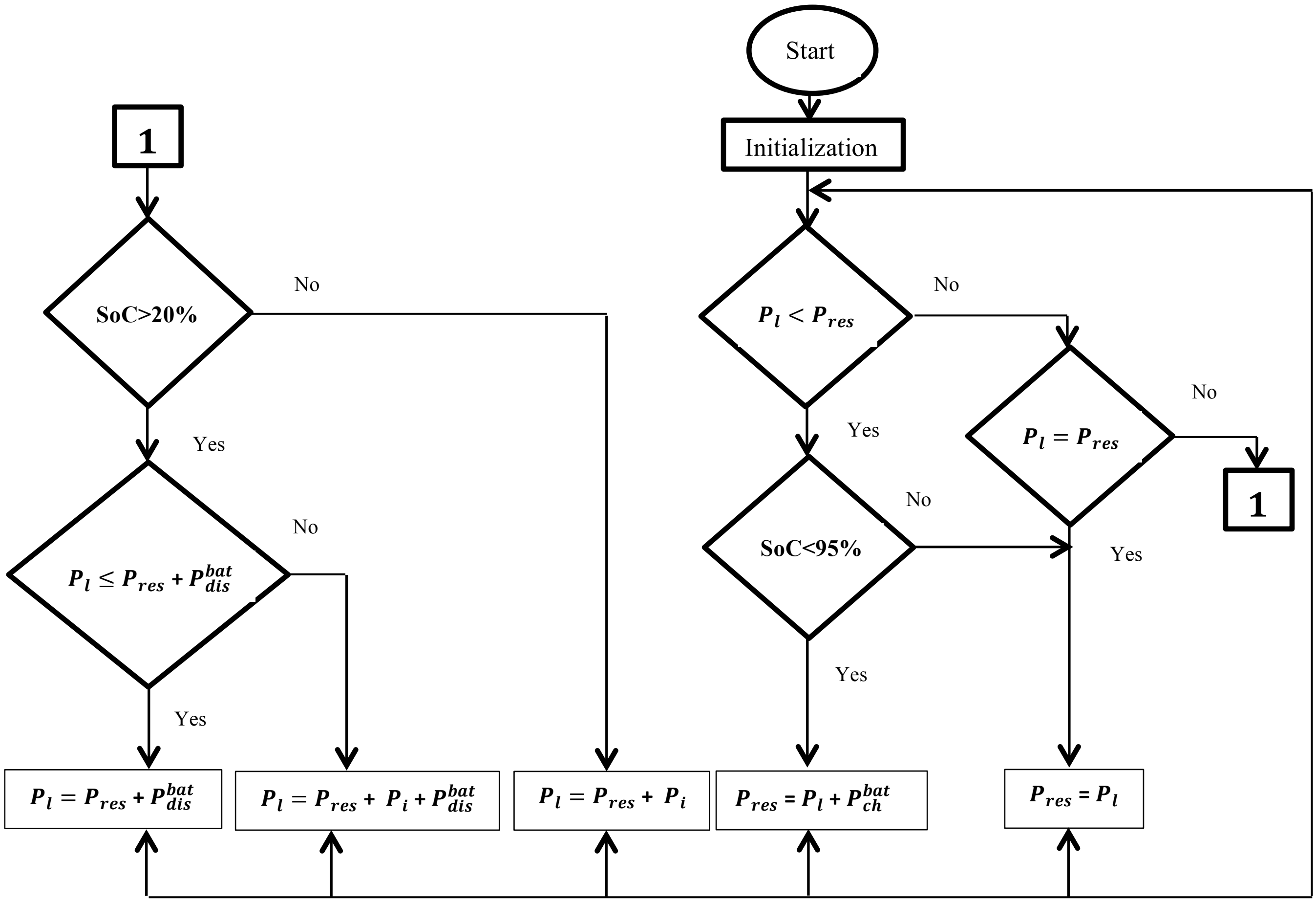

Fig. 6. Proposed process for EMS integrating ESS for optimizing the cost of energy production.

The proposed process in Fig.6 is composed based on RE (Wind energy, PV power generation), available and/or required energy of the battery, and power demand. The ESS has a different mode of work such as normal, excess energy, battery, and charging mode from renewables. The forms of operation for the suggested ESS strategy are given (see Fig.6). Additionally, the battery can be either positive or negative. The positive means that the battery acting as an energy source (discharge the energy) and negative signifies that the battery store the energy. The DGs level is managed by controlling the $A_{i,t}$ output power control variable, which is given in Equation (8). There are three cases in the proposed process presented in Fig.6:

Case 1: if the P_l< P_{res} and SoC< 95%, then the amount of RE would be supplied to ensure the load demand and the excess would be stored in the battery. In case of P_l=P_{res}, the amount of RE would be supplied to ensure the load only.

Case 2: if the SoC> 20%, and P_l≤ P_{res}+ P_{dis}^{bat}, then the a mount from RE and battery would be supplied to ensure the load demand. If it is not the case then the DGs are turned “on” to provide power.

Case 3: if the SoC<95%, then the DGs are turned “on” to support RE. The proposed EMS is implemented in GAMS environment.

4. Result and Discussion

The proposed process is performed in GAMS environment solved by OSICPLEX solver running on an Intel®Core™i5 4200 CPU (1.73 GHz~2.30 GHz) PC with 8 GB RAM. It is connected to 3-Generators units system as defined in Table III and characteristic of ESS unit is given in Table IV. The real data of grid load power demand, solar, and wind generation at different hours are given in Fig.2, Fig.3 and Fig.4 respectively. The simulation study is taken out for one day.

In this research, for an approach to reality, it is estimated that the generators can only participate in a portion of its capacity into the grid. This might be due to demand-supply requirements and technical constraints as follow:

$$\sum_{i=1}^{3} P_{i,t} \le \eta * 24 * \sum_{i} P_{i}^{\max} \tag{20}$$

This constraint is taken from [45]. Requiring this constraint with a robust strategy would make the scheduling problem between RE and DGs more challenging. In this work the value of η assumed to be 82, 28%. In this case, we declare that the charge still exists.

Energy sources:

Primary sources (P_s): renewable energy (solar and wind),

Secondary source[1] (S_{s1}): battery. The battery can provide energy if 20% < SoC < 95%. The battery maximum and

minimum SOC limits are held in constraint (15) in order avoiding the overcharging and/or discharging. These limits fix the battery don't charge and/or discharge below and above the limits.
Secondary sources[2] (S_{s2}): 3-generators. This procedure tries to guarantee the demand for good managing energy at a lower price.

4.1. Optimization Cost

The interest of the cost minimization is that one can explain a free market would develop at certain price levels. The optimization of energy production confirms if a variable production managed electric network can satisfy the load, without considering the cost. The parameters and the variables applied in this work are performed in Table 1, Table 2, Table 3 and Table 4, respectively.

4.2. Optimization cost of experiment result

The strategy will obtain the optimal solution, which will be the most economical system for meeting the needs. Throughout the operation, the system performed with the various production systems. The objective of the experiment is making a scheduling production between traditional and renewable energies. In other words, the system performed to reduce the cost of energy production to satisfy the loads and to generate the charging and discharging schedule of the battery.

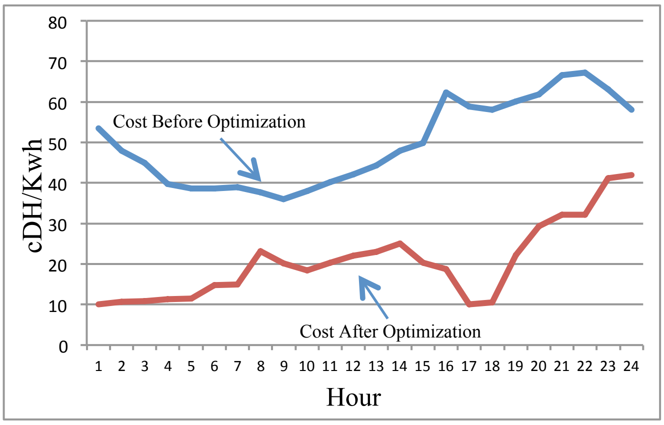

Fig. 7. Cost of energy production before and after optimization per period for one day.

The experiment results regarding the base case explain that the hourly running cost of the energy decrease by applying the MILP method and integrating the ESS into the production system. The achieved results can be analyzed versus the electrical load demand uncertainty. The variation weather data has an impact on the production cost differ according to timescales. In the previous work [46] linear programming is used to optimize energy production cost using RE and DGs only. The total cost for experiment1 decreases by 38%. Integrating the proposed strategy the price of this experiment decreases by 58.40%. In summary, the ESS has a significant part in minimizing the cost of production and supporting load demand.

4.3. Economic Scheduling

The objective of economic scheduling is determining the generation dispatch that minimizes the instantaneous operating cost, as mentioned in Table 2 three generators with different price are used. As observed, is the base case when the renewable energy and the battery are utilized to their maximum limit; i.e., maximum power output is taken from (PV, WT, and Battery) the operation cost decrease until 10.09 (cDH/Kwh). When the battery is in Idle or charging mode (from 09h to 16h), the price of energy production increase until 42.03 (cDH/Kwh). Also, the load demand growth at this time.

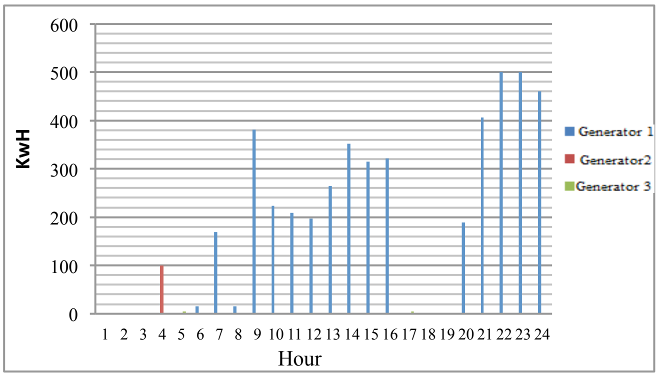

Fig. 8. The results of the generators contribution per period.

This trend continues (from 18h to 22h) where no further increment in load demand is mentioned. Moreover, the production from the generator increases at the same time to compensate for the need of the energy. From 0 hours to 3 hours DG1, DG2 and DG3 are turned "off" due to *ESS* SOC level is greater than 20% and $P_{res} \geq P_l$. Therefore, renewables with *ESS* supplies required power to customers. From 4 hours to 16 hours DG1, DG2 and DG3 are turned "on" due to the SOC level is less than 95% and $P_{res} \leq P_l$. The scheduling as an obtained result will be implemented for the whole day depending on power demand, level of renewables production and the battery level.

Additionally, the constraint (8) limits the total energy produced from the generators. If the demand at time t in progress, then the generators are persuaded to produce and supply its generated power in the forthcoming hours. Considering the available energy is limited and no renewables and energy storage device are available, at that time the outstanding hours of the day experience raise demand, it would decrease the benefits of the generators. The generating units are dispatched if the renewable energy with ESS cannot cover the power demand.

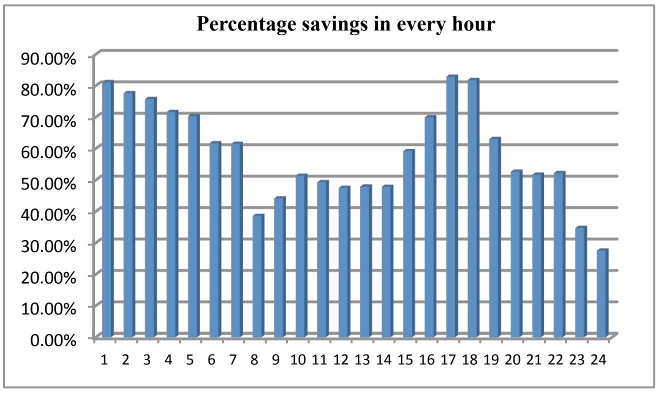

Fig. 9. Percentage savings in every hour for one day.

4.4. Tables

Table 1. The parameters of the model

Symbol	Quantity
P_{wg}	Power output of a wind generator
C_p	Turbine efficiency
η_{gb}	Gearbox efficiency
η_g	Generator efficiency
A_{wt}	Wind turbine swept area
Z	Elevation (m)
V	Wind speed (m/s)
ρ	Air density $[{}^{kg}/_{m^3}]$
T_a	Temperature(C)
P_{pv}	Power output of a photovoltaic generator
η_{pv}	Power conversion efficiency
A_{pv}	Surface area of PV panels (m2)
I_r	Solar radiance (W/m2)
η_r	Reference module efficiency
η_{pc}	Power conditioning efficiency
β	Generator efficiency temperature coefficient
T_c	Cell temperature (C). is the
$NOCT$	Normal operating cell temperature (C)
$P_{i,t}$	Power produced from generators at time t
$C_{i,t}$	Unitary cost of using the i^{th} generator at time t.
$P_{res,t}$	Power produced from renewable energies at time t
$P_{pv,t}$	Power produced by solar energy at time t.
$P_{w,t}$	Power produced by Wind energy at time t
$P_{dis,t}^{bat}$	Discharge Power of Battery
$P_{ch,t}^{bat}$	Charge Power of Battery
$A_{i,t}$	Binary variable {0, 1}
i	Index of units produced by generator {1, 2,3}
j	Index of units produced by renewable energy {1, 2}
B_t	Decision variable {0, 1}.
$P_{l,t}$	Power consumed by the load at a given time t.
ES_{max}^{bat}	Maximum battery energy level
ES_{min}^{bat}	Minimum battery energy level
Cap_{res}	Capacity of renewable energy
Cap_i	Capacity of generators
$\eta^{bat,ch}$	Battery charging efficiency
$\eta^{bat,ch}$	Battery discharging efficiency
P_{min}, P_{max}	Maximum and maximum active power capacity of generators

Table 2. Generators parameters

DG unit order	P_{min}	P_{max}	A	B
1	150	500	0.60	1.5
2	100	400	0.73	1.3
3	50	200	0.84	0.91

Table 3. Order of economic dispatch

DG unit order	Generator	A
1st	Generator1	0.60
2^{nd}	Generator2	0.73
3^{rd}	Generator3	0.84

The economic scheduling of generators unit is implemented according to the cost of energy production, presented in Table 2. As shown in Fig.8 the model uses the generators who have a high capacity of production at a low price respectively in all day to optimize the cost. As a result, presented in Fig.9, this approach optimizes the energy cost from 27.53% to 82.85% per hour.

Table 4. Battery parameter

Battery unit	$Energy_{min}$	$Energy_{max}$	P_{max} ch	P_{max} $Disch$
1	100	1000	100	100

4.5. Result of optimization charge/discharge

The charging/discharging of ESS for the working day is presented in Fig.10. The energy stored in the ESS differs in different hours. Additionally, for hour 24h the battery has not been used to supply the energy, because the discharge of the battery causes it to be charged throughout other hours. It's noted that the time of discharge is maximized compared with the time of charge to ensure the demand and to minimize the price.

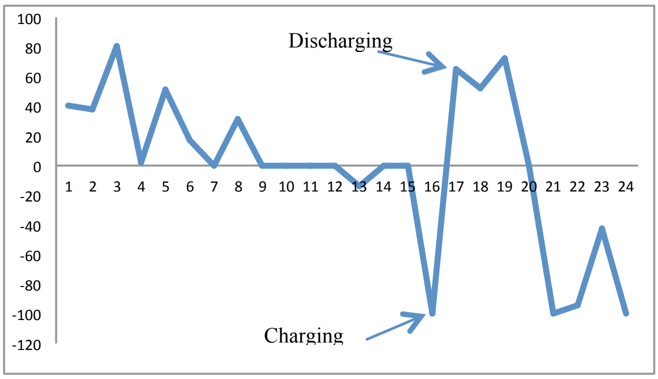

Fig. 10. Charging/Discharging of battery during the day (24h).

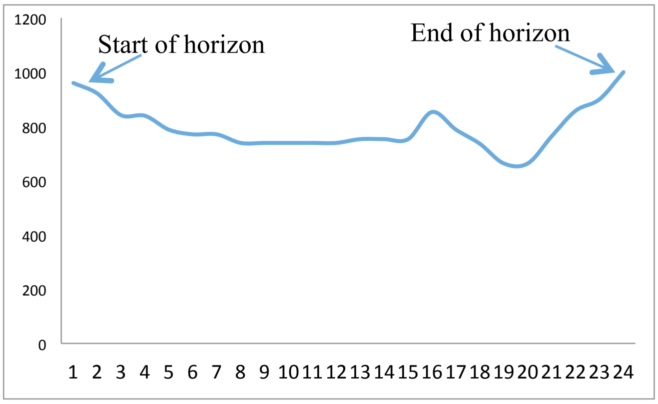

Fig. 11. Power of battery during the day (24h).

Figure10 and Figure11 explain the ESS power profiles, associated SOC and the power exchange between generators. From the experimental results some points can be drawn; first, as seen in Fig.8, the generators have a low excess of generation in comparison with the consumption. Since the ESS, discharge during most of the experiment, which in practice would allow for a reduction of the ESS rated capacity, or a lower limit for the maximum power consumed. Second, from Fig.7, a trend can be seen where the EMS, reduces the power consumption from the generators for the periods where the cost of electricity is high. The running cost of the operation has been assumed and estimated for diversity in the saved energy in the ESS. The minimizing of energy production from DGs and maximizing of power-sharing of ESS are given in Fig.8 and Fig.10. Although we would like to mention that our contribution is to design an organizational strategy of EMS that (a) reduces DGs operating hours, (b) maximize power-sharing from ESS, (c) economic scheduling for DGs, and (e) extends batteries lifetime by managing the battery charge and/or discharge rate. The reduced price of energy production and the DGs operating hours has been presented in Fig.7 and Fig.8. Besides, the rate of developments in the energy production is done in Fig.9 and Table 5. For managing the battery charge and/or discharge rate is proved in Fig.10. The operation of DGs energy is reduced for hour 4,5,6,7 and 8 and the DGs energy usage is further minimized (zero) in hour 1, 2, 3 and 18, 19 with a good managing of ESS and RE. The presented result in Table 5 determines the validity of the aimed strategy.

4.6. Environmental Evaluations

Decreasing the environmental impact is considered as important criteria to decide the utility of any project concerning its preservation for the environment. The amount of CO_2 emission reduced by using the hybrid system is calculated by the following [55].

$$Q_{emission\ reduced} = CE_s \tag{21}$$

C is national emission factor, which equals to 0.73121146(kgCO_2/ kWh), and E_s is energy saving. The value of Carbon Dioxide (CO_2) reduction is summarized in Table 5.

Table 5. Energy saving and(CO_2) reduction

	Daily average month
Daily Energy saving by PV (kWh)	1987,21
Daily Energy saving by WIND (kWh)	12190,81
Total Daily of Energy Saving (kWh)	14178,02
Tones (CO2)	10367.1307

5. Conclusion

In this paper, a process scheduling based on MILP method is suggested as a powerful strategy for energy management. The presented model analyzes the impacts of demand uncertainties and ESS unit on RE's benefits. The proposed method is employed in a system to prove its robustness. On the one hand, to reduce the production costs and the amount produced by the generators in the power system. On the other hand, to maximize the production from renewable energy and time of discharging the battery. The economic dispatch, energy storage and reduction schedule are taken into consideration. An excellent understanding of renewable resources production, future loads, and so on is assumed, which is useful to solve the optimization problem. An optimization-based on chance constrained optimization for managing the variation of renewable energy is formed. Different constraints arising in the practical application with specific strategy have been studied and developed. The application of this approach proves that the cost can be decreased until 82.85% every hour for one day. In summary, the optimization cost of energy production was studied, and CO_2 reductions are calculated to estimate economic and environmental impacts.

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