Anurag Shrivastava et al., J Nucl Ene Sci Power Generat Technol 2021, 10:10

Journal of Nuclear Energy Science & Power Generation Technology

Research Article

A SCITECHNOL JOURNAL

A Smart Grid Energy Management Optimization Technique

Anurag Shrivastava[1]*, Hari Kumar Singh[2], Praful Vijay Nandankar[3], Manoj Kumar Singh[4], Prateek Nigam[5] and Moti Lal Rinawa[6]

Abstract

Most of the population worldwide lives in remote rural areas thus face scarcity of electricity very often as few areas are connected with grid infrastructure, and most of the areas still depend on localized diesel-electric power for their livelihood. Continue research and development in the areas of sustainable renewable energy has made it possible to adopt DERs, which are very popular due to their low running cost, zero carbon footprint and autonomy in nature. The authors in this work have understood the need of the hour and attempted to create an energy-efficient integrated controller unit to address interconnectivity problems. The primary function of the proposed integrated controller shall be minimizing unwanted distortion, in turn, maintaining system stability to guarantee clean quality electricity to end consumers and optimizing resource use. Moreover, this article focuses on the design of a novel integrated utility controller circuit that can fulfill the combined goals of stability and optimality. MATLAB environment has been utilized to demonstrate the specific outcome that satisfies the Energy Management System (EMS) goal, including wind/solar PV/energy storage system/diesel generator. The authors in the proposed model have tried to incorporate an IOT kit in order to monitor the system parameter on a real-time basis. This shall help the operator monitor any unusual activities remotely, and immediate attentiveness and required troubleshooting mechanism can be initiated on an emergency basis.

Keywords: RES; Micro Grid; EMS; DG; Smart Grid

Introduction

A typical micro grid model, along with a suitable controller for the demonstration of renewable energy integration for a university load, is shown in Figure 1. It consists of the EMS along with the requisite circuitry for integrating the solar, wind, battery and diesel generator energy imparting systems.

The EMS for the proposed system is aimed to provide the following features.

- Energy forecast for wind and PV will be arranged by the EMS under which the penetration of renewable energy is ascertained
- Generation dispatch to minimize diesel use, which is the main aim to lessen the usage of conventional fossil fuel-based energy
- Smart Grid implementation for active power management and peak generation shaving
- Energy balancing
- Real-time remote monitoring of the system parameter using IOT configured kit

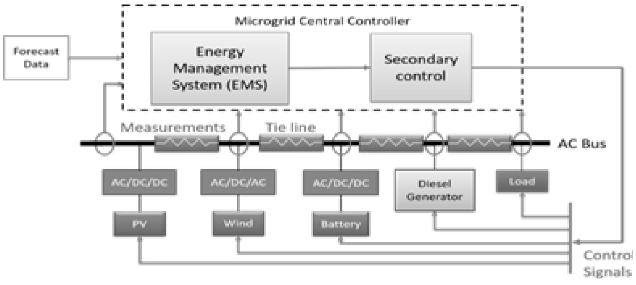

Figure 1: A micro grid layout.

The paper aims to reduce diesel fuel consumption by prioritizing wind and PV generation over diesel generation. Thus, the overall objective of the proposed EMS is to primarily coordinate the active power from various energy sources, including the wind, PV, diesel and energy storage system, to maintain voltage and frequency within a defined range of operation. The model proposed is a steady-state model which neglects fast order harmonics to see the capability of the Integrated Controller in the long term. This is due to the long life of batteries, health degradation, and other important performance indicators that could not be observed in a very short time scale.

Steady State Simulation Model

The system is made up of three major components: EMS, a micro grid model, and a nonlinear estimator. The EMS generates optimum power references for the micro grid using simplified equations, and a nonlinear estimator estimates the unknown states using nonlinear equations. This prevents errors from accumulating as a result of simpler models. While the system model operates in continuous simulation mode, EMS operates in discrete mode by performing computation and reference generation with a fixed time step. The nonlinear-estimator utilizes both modes to get distinct results since the State of Charge (SOC) must be calculated continuously while the State of Health (SOH) must be computed discretely. In this case, the pharos model of simulation in the Simulink simpowersystems toolbox is utilized, and rapid harmonics are ignored. The only thing that is intended to be monitored is the power flow in the system. A variable step solver with stiffness capture capability is also utilized for a quicker simulation.

System Description and Modeling

The system shown in Figure 2 is simulated in MATLAB. Figure 3 depicts the Simulink environment and system perspective. The primary goal of this study is to manage off-grid linked varied generating mix.

***Corresponding author:** Anurag Shrivastava, Principal and Professor Department of Electronics and Communication Engineering, Principal Lakshmi Narain College of Technology and Science, Indore, India, E-mail: Anuragshri76@gmail.com

Received date: September 06, 2021 **Accepted date:** September 22, 2021 **Published date:** September 29, 2021

The development of EMS for micro-grids is the primary emphasis. Forecasting load demand and generation, dispatching generating power, maintaining power balance in the system, and optimizing the functioning of energy units are all tasks of the EMS.

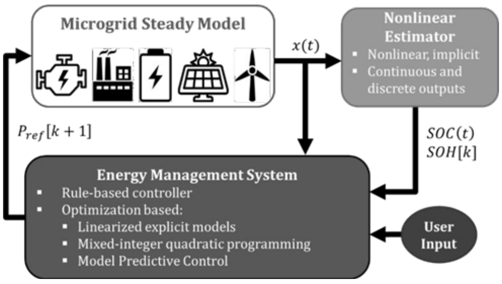

Figure 2: Block diagram of the entire micro grid-EMS-estimator system.

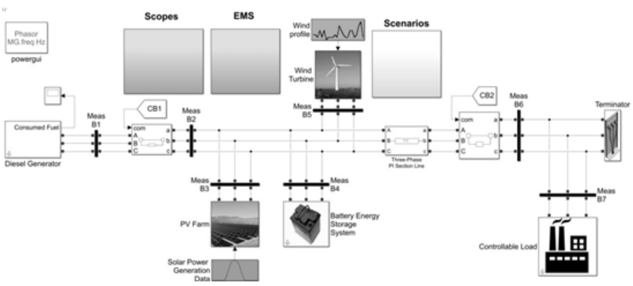

Figure 3: The proposed micro grid model.

Diesel Generator Model

The diesel generator unit is first modeled in a steady-state micro-grid model by a simplified synchronous generator and governor couple; however, it has been observed that this type of modeling approach drastically reduces simulation speed and makes it impossible to simulate the system for a very long-time duration. As a result, it is decided to utilize an ideal three-phase source. To prevent numerical instability issues, a fake/fictitious load of 50 W is also placed here. The active power taken from its bus is used to determine its fuel consumption Figure 4.

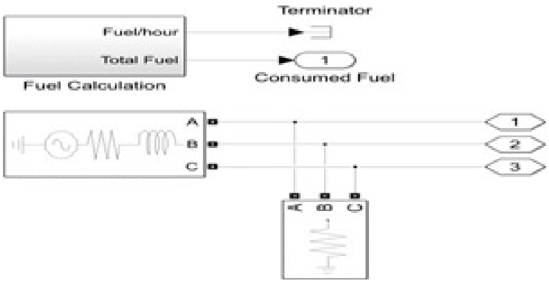

Figure 4: The simulated replacement of diesel engine generator.

This fuel consumption can be calculated via following equation [1,2]

$$C=\alpha+\beta\cdot Pg+\gamma u\cdot P2 \qquad (1)$$

Where C is the cost, Pg is the diesel generator power. α, β, γ are the parameters. The parameters are determined by curve fitting on datasheet data. In datasheet's fuel consumption value of a generator is taken at 4 different points such as 25%, 50%, 75% and 100% of nominal power. An example fuel consumption curve can be seen in Figure 5.

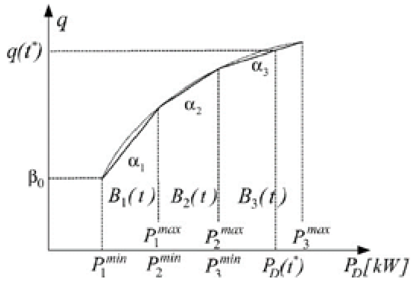

Figure 5: Diesel generator fuel consumption curve.

Wind Solar PV and Load Model

In the considered micro grid system, the renewable energy sources include wind and solar energy. In a real micro grid system, the wind and solar power and load are forecast using power forecasting methods. In the present simulation, it is assumed that the power has been forecast, and the forecast data is available. The forecast data has a resolution of one hour. Afterwards, a look-up table is used during the simulation. The wind turbine generator is having a power rating of 660 kW. The solar panel power rating is 350 kW the power for both DC and AC sides is given in the data file for the solar panel. The existing power data for one month, including wind and solar, are shown in Figures 6-8. Here, the negative value in the Photovoltaic (PV) power means the inverter consuming power at night. Taking one day as an example, the power data for wind, PV and load in 24 hours are shown in Figures 9-12.

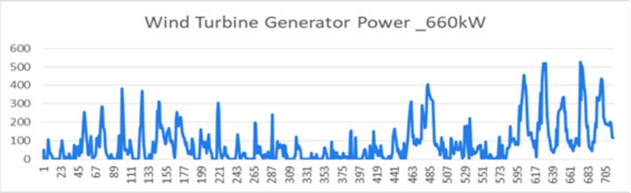

Figure 6: Wind power data for 660 KW turbine (one month).

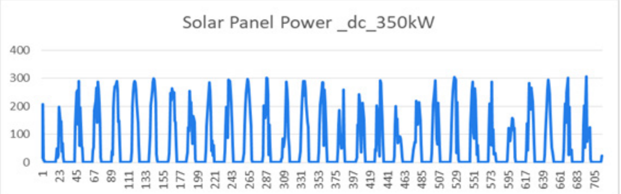

Figure 7: Solar power data at DC side (one month).

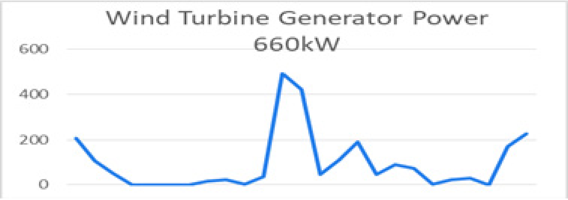

Figure 8: Wind power data for 660 KW turbines (one day).

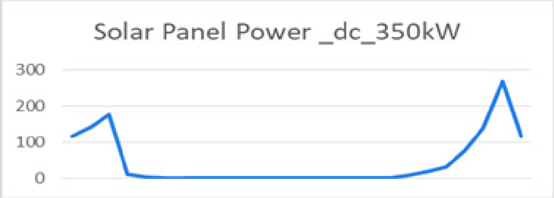

Figure 9: Solar power data at DC side (one day).

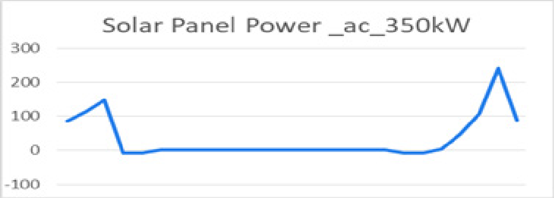

Figure 10: Solar power data at AC side (one day).

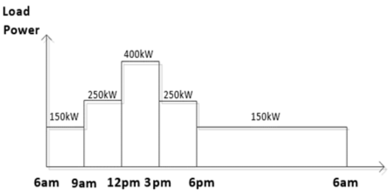

Figure 11: Load consumption data at AC side (one day).

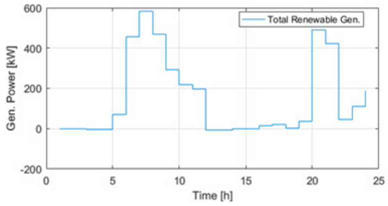

Figure 12: Total renewable generation.

Methodology

A combination of Model Predictive Control (MPC) [3] and Mixed-Integer Quadratic Programming (MIQP) [4,5] has been made use of in the paper with the following steps:

First, a suitable cost function and physical constraints (or desired boundaries) of the system are determined. While constructing the cost function, the function whose complexity does not exceed a quadratic polynomial is used. In addition to real variables, binary or integer variables can also be used constraints are also restricted in using only up to quadratic terms, and they also can contain integer/binary variables. After defining the cost function and constraints, a prediction horizon Nh is selected. This is the point where the MPC approach comes in the Multi-input multi-output processing capabilities along with the constraint handling properties of MPC are extremely helpful in such a scenario. All variables are concatenated into vectors that have Nh (Nh+1 for elements with the initial condition) elements inside, and the cost functions along the horizon are summed up [6].

Secondly, equations are written in a symbolic language to a file. In this paper, YALMIP (a free toolbox) is made use of as a parser that automatically maps the equation from symbolic variables to a language that the solver can understand [7].

Thirdly, an optimizer object is defined with its inputs and outputs to be able to solve optimization problems much faster. This optimizer works with the solver to find an optimal value. Here a free solver, GLPK is used, to solve optimization problems [8]. The optimizer is called to solve the problem at each predefined time step. It finds optimum values along the horizon; however, only the first element of the prediction horizon is applied to the system and at the next step optimization problem is solved again by using new measurements and estimations. Hence, feedback is introduced in the system. This is called the receding horizon strategy of MPC. First of all, a cost function containing all necessary objectives is built as

$$j=jdiesel+jrenewable \qquad (2)$$

Here 'j' denotes the overall cost function, which contains costs of each element where these elements are combined under a roof by using money equivalent. Here $jdiesel$ includes fuel cost given by [9] for the kth step

$$jdiesel=Dfuel\cdot\ (\alpha+\beta\cdot Pg+\gamma\ \cdot P2)+Dstartup\cdot\ |sgen\ (k+1)-(k)| \qquad (3)$$

Where, $Dfuel$ is the price of the fuel in Rs/L and inside parentheses amount of consumed fuel is calculated by using diesel generator power Pg and α, β, γ constants and the $Dstartup$ is the estimated price of switching on and off of diesel generator which is determined by binary variable Sgen indicating status (e.g., 1 for ON 0 for OFF) of diesel generator. Here the aim is to reduce the excessive fuel use as well as the frequent switch on and off of the diesel generator. In starting up cost of a generator is given by a curve that is the function of the generator's offline duration; however, it is assumed to be constant in the present case. Lastly, renewable cost consists of wind and solar curtailments are defined by

$$jrenewable=Dcwind\cdot Pcwind+Dcsolar\cdot Pcsolar \qquad (4)$$

Where, and $Dcsolar$ are weights of curtailing wind and solar power respectively, and Pcwind and Pcsolar are curtailed power for wind and solar generation. Curtailed powers are defined by

$$Pcwind=\sigma windPwind \qquad (5)$$

$$Pcsolar=\sigma solarPsolar \qquad (6)$$

Where σ variables are curtailment rates (between 0and1) and generation from wind and solar renewables, respectively. Pwind and Psolar are predicted power.

A micro grid can be transformed into a smart grid by systematically integrating cutting-edge tools like AI, ML, IOT, block chain, cloud

Citation: *Shrivastava A, Kumar Singh H, Vijay Nandankar P, Kumar Singh M, Nigam P, et al., (2021) A Smart Grid Energy Management Optimization Technique. J Nucl Ene Sci Power Generat Techno 10:10*

computing, PLC, etc. The authors have attempted to provide a provision for linkage of IOT on a need basis. This shall be beneficial to retrieve real-time data and analyses them to get necessary findings and the overall behavioral nature of the tied plant.

System Constraints

As well as having a proper cost function, setting constraints is also significant to achieve a meaningful solution for the optimization problem. The system constraints are summarized in Table 1. It may be seen that every power reference has upper and lower bounds. However, for diesel generators, on/off variables are also included to force generated power to be zero when the generator is not working. Additionally, we also have limits on other variables as SOC [10].

Table 1: System constraints has been shown.

Battery constraints	SOCmin ≤ SOC(k) ≤ SOCmax
	Pbamin ≤ pt (k) ≤ Pbamax
Diesel generator constraints	Sgen(k).Pgenmin ≤ Pg(k) ≤ Sgen(k). Pgenmax
Renewable generation constraints	Σwindmin ≤ σwind(k) ≤ σ windmax
	Σ solarmin ≤ σsolar(k)≤ σ solarmax
Power flow constraints	Pg(k)=Pload(k)+Pt(k)-σ'wind(k) Pwind(k)-σ'solar(k)psolar(k)

Table 2: Numerical values of system parameters.

Parameter	DGs			
	Solar	Wind	Energy storage	Diesel Generator
Power rating	330kW	650 kW	500 Kw	500 kW
Rated voltage	440V (L-L)	440V (L-L)	440V (L-L)	440(L-L)
EMS parameters				
SOCmin,SOCmax	0.2, 0.8	b,c	1.75e-5, 0.2914 L/kWh 10, 500 kW 12 hours 25 degrees Celsius	
Pbatmin, Pbatmax	-500, 500 kW	Pgenmin, Pgenmax		
σ windmin, σwindmax	0,0.8	Nh		
σsolarmin, σ sloarmax	0,1	Tc		

Where $\sigma' solar$ and $\sigma' wind$ are reciprocals of $\sigma solar$ and $\sigma wind$, and defined by

$$\sigma' = 1 - \sigma \qquad (7)$$

It is used to find un-curtailed power.

Results and Discussion

Before proceeding with the simulations of the system, the numerical values of the parameters need to be pre-defined. The behavior of various sources (i.e., renewables, battery, diesel generator) within the constraints presented is such that there is minimum usage of the diesel generator, as can be seen from the Figures 13-15 below. The combined outputs from the wind and solar powers according to the patterns given in Figures 6-11, are represented in Figure 13. Battery power, state of charge and state of the health of the battery is represented in Figure 14

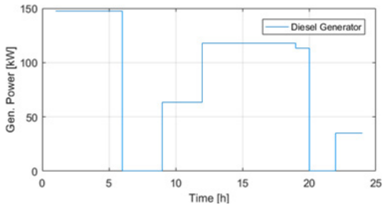

Figure 13: Diesel generator generation.

Figure 15 shows that the various sources exactly cater for the desired load. As seen from the above-given figures, the proposed EMS system can balance the power and generate power references.

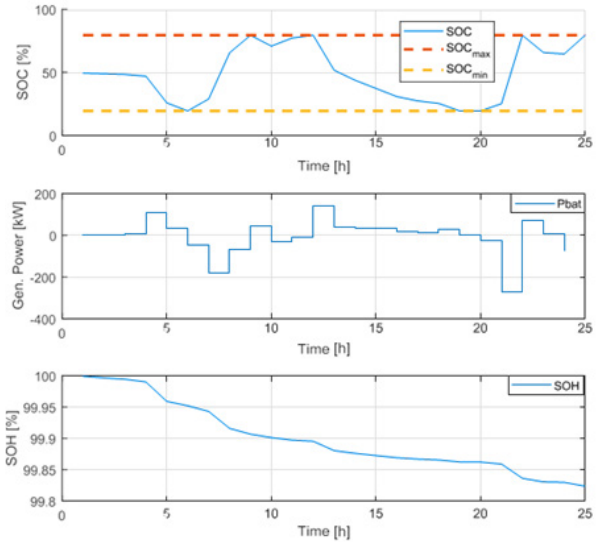

Figure 14: Battery status (SOC, Pbat, SOH).

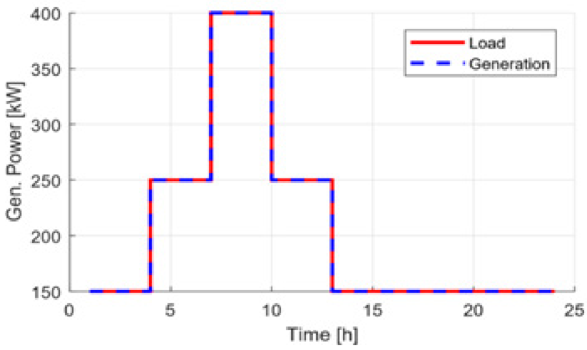

Figure 15: Load and total generation.

Conclusion

The paper's primary goal was to balance the electricity from renewables, batteries, and diesel generators. The micro-grid model in this article is developed in mat lab/Simulink. The Simulink model includes the EMS algorithm is then applied to the whole system. The diesel generator unit, wind energy, solar energy, energy storage system, and load are all part of the micro-grid. All of these units are linked to a micro grid, and the system functioning is defined and optimized by the EMS algorithm. The goal is clearly to reduce the need for diesel generators, thus conserving valuable fossil-based fuel. This paper is capable of designing an EMS capable of power balancing, and as can be shown, the effective balancing of the power required by the loads is accomplished. Although problems like robustness, carbon emissions, and maintenance costs have not been taken into account, it can be fairly said that the EMS is capable of delivering the basic characteristics of a smart grid. Although less discussion has been made on IOT embedded kit because its operation can only be validated in a physical, practical system. Research work is in progress, and after getting a satisfactory specific outcome, it shall be highlighted in the next work.

References

1. Djuroviczivic M, Milacic A, Krsulja M (2012) A simplified model of quadratic cost function for thermal generators. In Proceedings of the 23rd Daaam Symposium 23: 25–28.
2. Carrión M, Arroyo JM (2006) A computationally efficient mixed-integer linear formulation for the thermal unit commitment problem. IEEE Trans Power Syst 21: 1371–1378.
3. Garcia F Bordons C (2013) Optimal economic dispatch for renewable energy microgrids with hybrid storage using model predictive control. IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society pp: 7932-7937.
4. Heussen K, Koch S, Ulbig A, Andersson G (2012) Unified system-level modeling of intermittent renewable energy sources and energy storage for power system operation. IEEE Syst J 6: 140–151.
5. Banik A, Sengupta A (2021) Scope challenges opportunities and future goal assessment of floating solar park. Innovations in Energy Management and Renewable Resources (52042) pp: 1-5.
6. Banik A, Shrivastava A, Manohar Potdar R, Kumar Jain S, Nagpure SG, et al. (2021) Design Modelling and Analysis of Novel Solar PV System using MATLAB. Mater Today: Proc.
7. Löfberg J (2004) Yalmip: A toolbox for modeling and optimization in matlab. IEEE International Conference on Robotics and Automation pp: 284-289.
8. Kumtepeli V, Wang Y, Tripathi A (2016) Multi-area model predictive load frequency control: A decentralized approach. Asian Conference on Energy Power and Transportation Electrification (ACEPT) pp: 1–5.
9. Palma BR, Benavides C, Lanas F, Severino B, Reyes L, et al. (2013) A micro grid energy management system based on the rolling horizon strategy. IEEE Trans Smart Grid 4 : 996–1006.
10. Das TK, Banik A, Chattopadhyay S, Das A (2021) Energy-efficient cooling scheme of power transformer: an innovative approach using solar and waste heat energy technology. In: Ghosh SK, Ghosh K, Das S, Dan PK, Kundu A (eds) Advances in Thermal Engineering Manufacturing and Production Management. ICTEMA 2020. Lecture Notes in Mechanical Engineering pp: 201-208.

Author Affiliations

Top

[1]Department of Electronics and Communication Engineering, Lakshmi Narain College of Technology and Science, Indore, India

[2]Department of Electronics and Communication Engineering, MJP Rohilkhand University Bareilly, UP, India

[3]Department of Electrical Engineering, Government College of Engineering, Nagpur, Maharashtra, India

[4]Department of Mechanical Engineering, FET MJP Rohilkhand University Bareilly, UP, India

[5]Department of Electrical and Electronics Engineering, Rabindranath Tagore University, Bhopal, India

[6]Department of Mechanical Engineering, Government Engineering College, Jhalawar, India