

# **Bi-Level Multi-Objective Planning Model of Solar PV - Battery Storage-Based DERS in Smart Grid Distribution System**

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## **Abstract**

The Bi-level Multi-Objective Planning Model of Solar PV-Battery Storage-Based DERS in Smart Grid Distribution System is a research paper that proposes a planning model for the implementation of distributed energy resources (DERs) in a smart grid distribution system. The model is designed to optimize the deployment of solar PV and battery storage systems in the grid, while taking into account various technical, economic, and environmental factors. The proposed planning model is based on a bi-level multi-objective optimization approach, which considers both the objectives of the utility and the objectives of the DER owners. The upper-level objective is to minimize the total cost of energy supply to the grid, while the lower-level objective is to maximize the revenue of the DER owners. The model is implemented using a genetic algorithm, which is used to search for the optimal solution.

The model is also capable of considering the uncertainties associated with solar PV and battery storage systems, such as weather conditions and battery degradation. The results of the study show that the proposed planning model can effectively optimize the deployment of solar PV and battery storage systems in a smart grid distribution system. The model is also shown to be robust to various uncertainties associated with DERs, such as weather conditions and battery degradation. Overall, the proposed planning model provides a valuable tool for the implementation of distributed energy resources in a smart grid distribution system. By optimizing the deployment of DERs, the model can help to reduce the cost of energy supply, while also improving the reliability and environmental performance of the grid.

This project describes the multi objective battery sizing and storage system for grid connected system using renewable energy solar and wind system.

## **Introduction**

The increasing demand for electricity and the growing environmental concerns have led to a significant interest in the implementation of distributed energy resources (DERs) in smart grid distribution systems. The use of DERs, such as solar photovoltaic (PV) and battery storage systems, can help to improve the reliability, efficiency, and environmental performance of the grid. However, the implementation of DERs in a smart grid distribution

system requires careful planning and optimization to ensure that the technical, economic, and environmental objectives are met. In particular, the deployment of DERs must take into account the objectives of both the utility and the DER owners, which can often be conflicting. To address these challenges, this research paper proposes a bi-level multi-objective planning model for the implementation of solar PV and battery storage-based DERs in a smart grid distribution system. The proposed model considers both the objectives of the utility and the objectives of the DER owners, and is designed to optimize the deployment of DERs while taking into account various technical, economic, and environmental factors. The upper-level objective of the proposed model is to minimize the total cost of energy supply to the grid, while the lower-level objective is to maximize the revenue of the DER owners. The model is implemented using a genetic algorithm, which is used to search for the optimal solution. The proposed model also takes into account the uncertainties associated with solar PV and battery storage systems, such as weather conditions and battery degradation. The model is capable of considering various scenarios and can provide insights into the optimal deployment of DERs under different conditions. Overall, the proposed bi-level multi-objective planning model provides a valuable tool for the implementation of solar PV and battery storage-based DERs in a smart grid distribution system. The model can help to reduce the cost of energy supply, while also improving the reliability and environmental performance of the grid.

During the last decade, the importance of new technologies and changes in incentive policies and governmental regulations have led to the power grid being smarter, more reliable, and more distributed. This paper aims to introduce a novel optimization approach of the grid-connected PV battery system under a time-of-use (TOU) dynamic pricing scheme to a developing country to achieve the optimum system sizing for residential prosumers to achieve two converse objectives. The economic feasibility of using the batteries in this PV system is introduced using the net present value (NPV) and the annual bill savings.

## **Existing System**

### **Optimizng Standalone Pv System**

The real world problem which are non-differentiable, non-linear, continuous and real valued can be solved to obtain global optimal solutions by these (GA, DE, PSO) modern stochastic algorithm. Hence in this work, each of these algorithm is simulated and compared for the design optimization of standalone PV system

## **Proposed System**

### **Software Block Diagram**

### **Software Description**

#### **PV system modeling**

The PV grid-connected system considered in this work consists of the PV arrays, the DC/AC inverter, and the utility grid, as shown in Fig. 1. The PV arrays absorb the solar energy and convert it to direct current (DC) power,  $P_{pv}$ . The DC/AC inverter receives the DC power and converts it to an alternating current (AC) power,  $P_{inv}$ . The utility grid and loads are directly

connected to the common coupling point without any interfacing power conditioning device. Initially, the load, i.e., demand, can

### 3.3.3 Algorithm Description

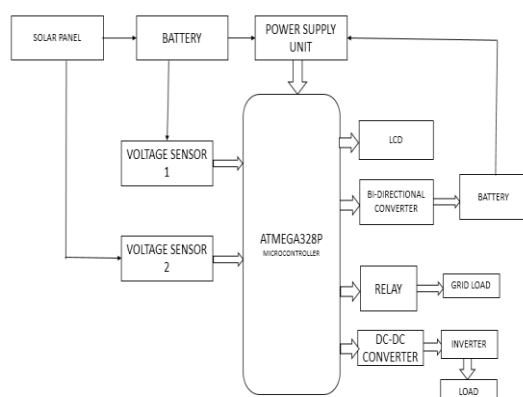
Constraint limits the BESS capacity range between given minimum and maximum values (denoted with  $C_{min}$  and  $C_{max}$ , respectively) due to technology or regulatory requirements. Constraint ensures that in the time interval  $[t_0, t_0+T]$  the Root Mean Square (RMS) voltages  $V_{bp}(t_0, T, x)$  of the B three-phase buses connected to the REC members are included within the DSO-compliant interval  $[V_L, V_U]$  with a probability at least equal to  $q\alpha$ . The values of  $V_L$ ,  $V_U$  and  $q\alpha$  depend on local, national or international regulations about voltage stability. In general,  $B \geq N$  due to the presence of zero-injection buses, which are very common at the distribution level

Finally, the linear equality constraint (1c) prevents that BESSs are assigned to the REC members that do not want or cannot install them. In particular, if  $U$  is a  $N \times N$  diagonal matrix, if the  $i$ -th diagonal element is different from 0 (i.e., equal to 1), the  $i$ -th equation extracted from (1c) is satisfied if and only if  $x_i = 0$ . This means that the nonzero diagonal elements of  $U$  are used to identify the REC members that have to be excluded from optimal BESS sizing

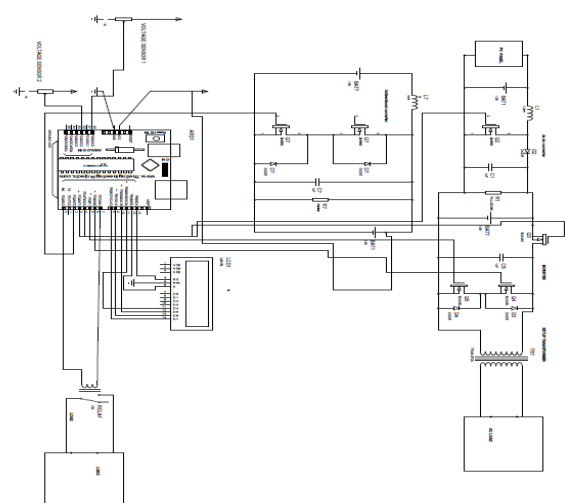
### Problem Solution

The BESS optimization problem (1) was solved by means of a custom implementation of the NSGA-II algorithm. The BESS capacity values of the N REC members (namely the decision variables of problem (1)) are regarded as the genes of an N-sized chromosome. The NSGA-II algorithm requires an initial  $2M$ -sized population of chromosomes,  $M$  of which change at every iteration as a result of the evolutionary process. Of course, the value of  $M$  as well as the genetic variety of the initial population must be large enough to ensure a thorough exploration of the solution space. A simplified flowchart of the developed implementation

### Hardware Block Diagram

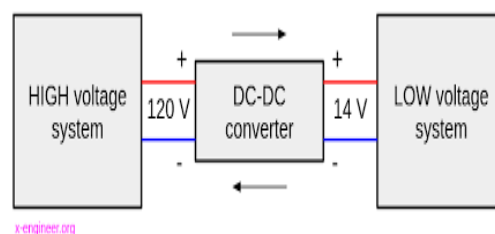


HARDWARE BLOCK DIAGRAM  
 CIRCUIT DIAGRAM



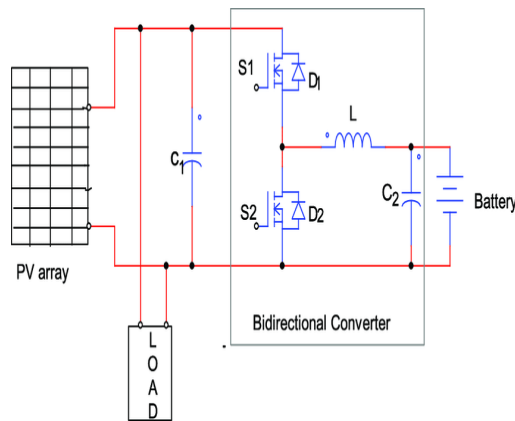
CIRCUIT DIAGRAM

The DC-to-DC converters convert one level of DC voltage to another level. The operating voltage of different electronic devices such as ICs, MOSFET can vary over a wide range, making it necessary to provide a voltage for each device. A Buck Converter outputs a lower voltage than the original voltage, while a Boost Converter supplies a higher voltage. The working principle of the DC-to-DC converter is very simple. The inductor in the input resistance has an unexpected variation in the input current. If the switch is kept as high (on), then the inductor feeds the energy from the input and stores the energy in the form of magnetic energy. If the switch is kept as low (off), it discharges the energy. Here, the output of the capacitor is assumed as high that is sufficient for the time constant of an RC circuit on the output side. The huge time constant is compared with the switching period and made sure that the steady-state is a constant output voltage. It should be  $V_o(t) = V_o(\text{constant})$  and present at the load terminal.



**Bidirectional Converter**

A bidirectional converter is a device that can convert a signal or data from one form to another in both directions. This means that it can convert the signal or data from its original form to the target form, as well as from the target form back to the original form. Bidirectional converters are commonly used in computer networking and communication systems, where data needs to be transferred between two different types of networks or protocols. For example, a bidirectional converter might be used to convert data between Ethernet and Wi-Fi, or between USB and RS-232. Bidirectional converters can also be used in power electronics, where they are used to convert power between different types of DC voltage sources or between DC and AC power sources. These types of bidirectional converters are commonly used in renewable energy systems, where energy can be generated from sources like solar or wind power and then fed into the grid or stored in batteries. The bidirectional converters are an important tool for enabling interoperability between different systems and for efficiently managing the transfer of data or power between different types of sources and loads.



## Software Specification

### Matlab 17a

MATLAB (matrix laboratory) is a numerical computing environment and fourth-generation programming language. Developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and Fortran. Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPADsymbolic engine, allowing access to symbolic computing capabilities. An additional package, Simulink, adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems.

In 2004, MATLAB had around one million users across industry and academia. MATLAB users come from various backgrounds of engineering, science, and economics. MATLAB is widely used in academic and research institutions as well as industrial enterprises.

### Developing Algorithms And Applications

MATLAB provides a high-level language and development tools that let you quickly develop and analyze your algorithms and applications.

### ANALYZING AND ACCESSING DATA

MATLAB supports the entire data analysis process, from acquiring data from external devices and databases, through preprocessing, visualization, and numerical analysis, to producing presentation-quality output.

### Data Analysis

MATLAB provides interactive tools and command-line functions for data analysis operations, including:

- Interpolating and decimating
- Extracting sections of data, scaling, and averaging
- Thresholding and smoothing
- Correlation, Fourier analysis, and filtering
- 1-D peak, valley, and zero finding

- Basic statistics and curve fitting
- Matrix analysis

### **Data Access**

MATLAB is an efficient platform for accessing data from files, other applications, databases, and external devices. You can read data from popular file formats, such as Microsoft Excel; ASCII text or binary files; image, sound, and video files; and scientific files, such as HDF and HDF5. Low-level binary file I/O functions let you work with data files in any format. Additional functions let you read data from Web pages and XML.

### **Visualizing Data**

All the graphics features that are required to visualize engineering and scientific data are available in MATLAB. These include 2-D and 3-D plotting functions, 3-D volume visualization functions, tools for interactively creating plots, and the ability to export results to all popular graphics formats. You can customize plots by adding multiple axes; changing line colors and markers; adding annotation, Latex equations, and legends; and drawing shapes.

### **2-D Plotting**

Visualizing vectors of data with 2-D plotting functions that create:

- Line, area, bar, and pie charts.
- Direction and velocity plots.
- Histograms.
- Polygons and surfaces.
- Scatter/bubble plots.
- Animations.

### **3-D Plotting and Volume Visualization**

MATLAB provides functions for visualizing 2-D matrices, 3-D scalar, and 3-D vector data. You can use these functions to visualize and understand large, often complex, multidimensional data. Specifying plot characteristics, such as camera viewing angle, perspective, lighting effect, light source locations, and transparency.

3-D plotting functions include:

- Surface, contour, and mesh.
- Image plots.
- Cone, slice, stream, and is surface.

### **Performing Numeric Computation**

MATLAB contains mathematical, statistical, and engineering functions to support all common engineering and science operations. These functions, developed by experts in mathematics, are the foundation of the MATLAB language. The core math functions use the

LAPACK and BLAS linear algebra subroutine libraries and the FFTW Discrete Fourier Transform library. Because these processor-dependent libraries are optimized to the different platforms that MATLAB supports, they execute faster than the equivalent C or C++ code. MATLAB provides the following types of functions for performing mathematical operations and analyzing data:

- Matrix manipulation and linear algebra.
- Polynomials and interpolation.
- Fourier analysis and filtering.
- Data analysis and statistics.
- Optimization and numerical integration.
- Ordinary differential equations (ODEs).
- Partial differential equations (PDEs).
- Sparse matrix operations.

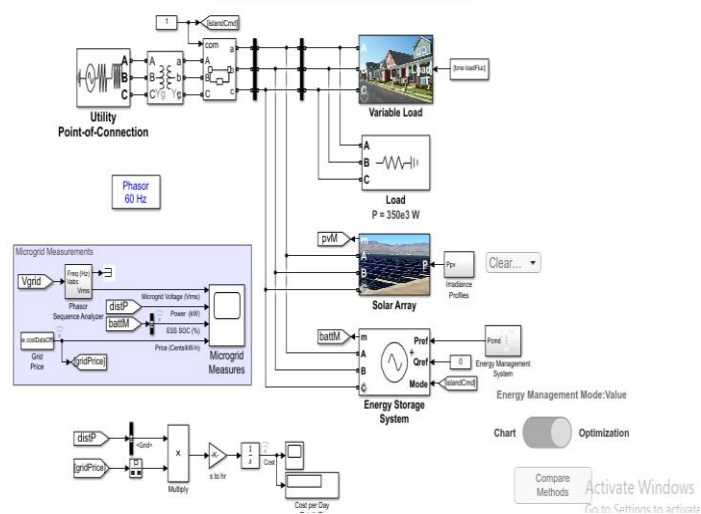
MATLAB can perform arithmetic on a wide range of data types, including doubles, singles, and integers.

## **Software Requirements**

### **Arduino Ide**

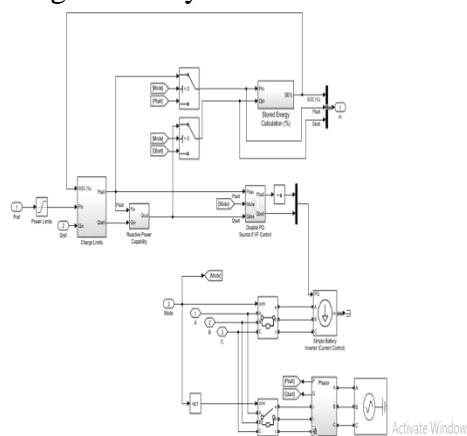
The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It is used to write and upload programs to Arduino board. The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring.<sup>[4]</sup> The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub `main()` into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program argued to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board

## Simulation Results

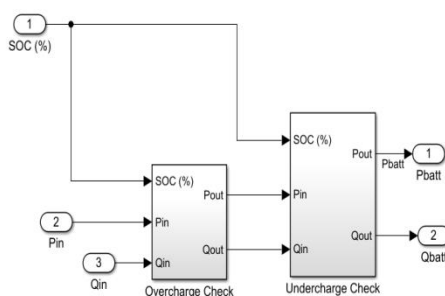


### Solar With Grid System

Here we designed solar with battery system and with battery energy storage system. Most batteries used are lead-acid type in hybrid systems. A simple model is shown in figure 2. It consists of an ideal battery with open-circuit Voltage  $V_o$ , a constant equivalent internal resistance  $R_{bat}$  and terminal voltage  $V_{battery}$ .

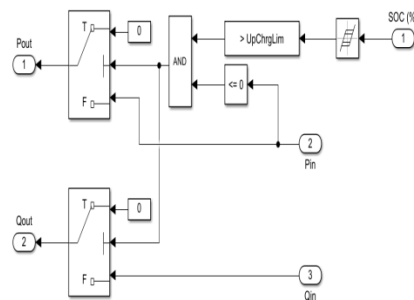


### controller of dynamic load

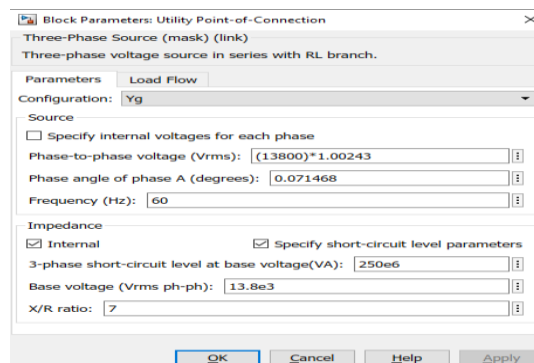


### over voltage and under voltage



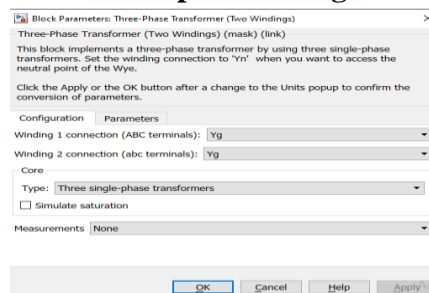


**Controller of the system  
Input voltage**



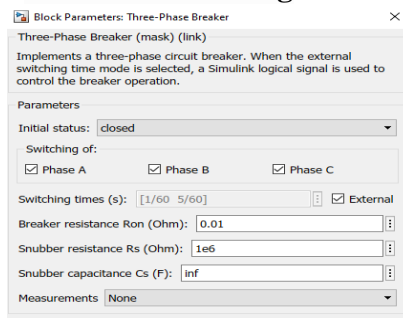
Here we designed the input voltage and phase to phase voltage with grid connected system 13kv with grid connected system is input to the system

### Three phase voltage

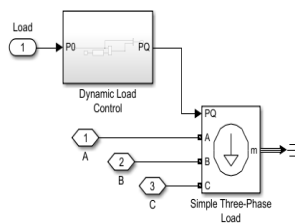


Three phase transformer integrated with configuration is phase to phase to voltage is integrated on this system

### Transformer rating

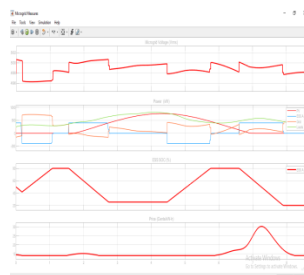
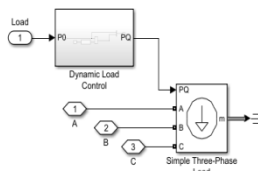


### three phase load

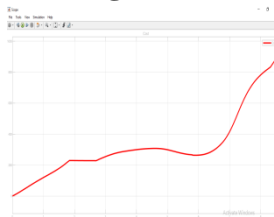


Three phase dynamic load is configured is integrated dynamic load voltage is connected to this system.

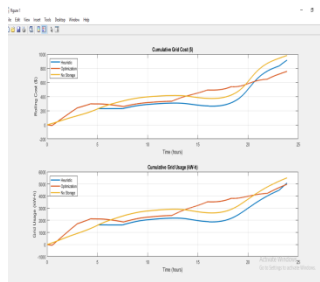
### Three phase RLC load



**Figure: microgrid voltage and solar system and ESS**



### cost variation in result

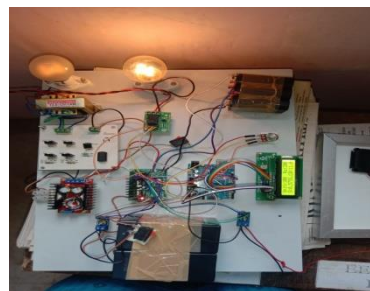


### Grid usage and rolling cost analysis

## TEST REPORT OFF CONDITION



## ON CONDITION



### Conclusion

The bi-level multi-objective planning model of solar PV-battery storage-based DERS in smart grid distribution systems is a promising approach to managing energy resources in a sustainable and cost-effective manner. This model considers the integration of renewable energy resources, such as solar photovoltaic (PV) systems and battery storage, into the distribution system, while taking into account the multiple objectives of the stakeholders involved. By using a bi-level optimization approach, this model can effectively balance the objectives of the distribution system operator (DSO) and the prosumers (i.e. consumers who also produce energy), while ensuring that the system operates within the technical and regulatory constraints. The use of solar PV-battery storage-based DERS has the potential to

reduce the dependency on traditional fossil fuel-based energy sources and lower greenhouse gas emissions.

Moreover, the use of bi-level optimization can provide a fair and efficient way to allocate the benefits and costs associated with the integration of DERS among the different stakeholders. Overall, the bi-level multi-objective planning model of solar PV-battery storage-based DERS in smart grid distribution systems is a promising approach that can help to achieve a more sustainable, reliable, and efficient energy system. However, further research and development are needed to fully realize its potential and address the challenges associated with its implementation.

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