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Design and Analysis of HEMS (EV, PV, ESS, RT Appliances) using MATLAB

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Abstract: *In this project, we proposed a home energy management system (HEMS) that includes photovoltaic (PV), electric vehicle (EV), and energy storage systems (ESS). The proposed HEMS fully utilizes the PV power in operating domestic appliances and charging EV/ESS. The surplus power is fed back to the grid to achieve economic benefits. A novel charging and discharging scheme of EV/ESS is presented to minimize the energy cost, controlthe maximum load demand, increase the battery life, and satisfy the user's-traveling needs. TheEV/ESS charges during low pricing periods and discharges in high pricing periods. In the proposed method, a multi-objective problem is formulated, which simultaneously minimizes the energy cost, peak to average ratio (PAR), and customer dissatisfaction. The multi-objectiveoptimization is solved using binary particle swarm optimization (BPSO). The results clearly show that it minimizes the operating cost from 402.89 cents to 191.46 cents, so that a reduction of 52.47% is obtained. Moreover, it reduces the PAR and discomfort index by 15.11% and 16.67%, respectively, in a 24 h time span. Furthermore, the home has home to grid (H2G) capability as it sells the surplus energy, and the total cost is further reduced by 29.41%.*

Keywords: Energy Grid, Electric Vehicle, Single Feed, Solar, Photo Voltaic, Battery, Distribution, Bidirectional Controller.

I. INTRODUCTION

Energy demand increases very sharply day by day. To overcome this problem and optimize the power generated, researchers have proposed various effective strategy. Consumers may shift their domestic appliances usage from peak hour to off-peak hour to achieve economic benefits. To achieve the benefits a HEMS is required at home. The HEMS optimally schedules domestic usage to reduce electricity bills. Moreover, HEMS increases consumer comfort, reduces peak-to-average ratio (PAR), and minimizes the burden on the grid. Several HEMS strategies have been proposed in the literature. They formulate a multi- objective optimization problem that considers bill minimization and user comfort as system objectives. Optimum scheduling of home appliances in an off-peak period may increase the peak-to-average ratio, which increases the burden on power utility and causes grid failure. To handle the problem of overloading, some researchers have considered PAR as one of the objectives or constraints in optimization problems. The contribution of this project concludes as follows:

1. Includes PV, EV, and ESS simultaneously to minimize the operating cost.
2. Fully utilizes the PV power by shiftable appliances, EV, and ESS while the surplus power is fed back to the grid for economic benefits.
3. The charging and discharging schemes have been presented, including the constraints of ESS and EV. The scheme utilizes the RTP, maximum demand limit, and availabilityof EV to rationally manage the energy flow between home and utility. The EV and ESSare charged during low RTP periods and provide power to peak energy periods.
4. A multi-objective problem is formulated, which minimizes the operating cost, PAR,and user's discomfort simultaneously in the HEMS paradigm.

II. SOFTWARE USED: MATLAB

MATLAB is a programming and numeric computing platform used by millions of engineers and scientists to analyze data, develop algorithms, and create models. MATLAB® combines a desktop environment tuned for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly. It includes the Live Editor for creating scripts that combine code, output, and formatted text in an executable notebook. MATLAB toolboxes are professionally developed, rigorously tested, and fully documented. MATLAB apps let you see how different algorithms work with your data. Iterate until you've got the results you want, then automatically generate a MATLAB program to reproduce or automate your work. Scale your analyses to run on clusters, GPUs, and clouds with only minor code changes. There's no need to rewrite your code or learn big data programming and out-of- memory techniques. MATLAB (an abbreviation of "MATrix Laboratory") is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks.

MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages. Although MATLAB is intended primarily for numeric computing, an optional toolbox uses the MuPAD symbolic engine allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. As of 2020, MATLAB has more than 4 million users worldwide. They come from various backgrounds of engineering, science, and economics.

The main objectives of the system are as follows:

- Include RT Loads, PV, EV, and ESS simultaneously to minimize the operating cost.
- Fully utilize the PV power by real time appliances, EV, and ESS while the surplus power is fed back to the grid for economic benefits.
- The charging and discharging schemes need to be presented, including the constraints of ESS and EV. The scheme utilizes the RTP, maximum demand limit, and availability of EV to rationally manage the energy flow between home and utility. The EV and ESS are charged during low RTP periods and provide power to peak energy periods. The discharging power is utilized by domestic appliances while the surplus power is sold back to the grid.
- A multi-objective problem is formulated, which minimizes the operating cost, PAR, and user's discomfort simultaneously in the HEMS paradigm.

III. METHODOLOGY

Home energy management system (HEMS) concept rises from the development of smart homes that build interaction between users with their home appliances in order to operate automatically, multi-functionally, adaptably and efficiently. In line with technological developments and published regulations related to environmental issues, smart home applications evolve into HEMS applications which are not only to provide ease and convenience, but also to monitor and to make efficient energy use at home, thereby reducing peak power quantity and electricity bill. Smart grid is an intelligent power grid starting from its generation, transmission and distribution. It combines computing technology, artificial intelligence and communications technology which creates a smarter power system and is able to produce better power quality and lower generation cost. In the smart grid scheme, by means of HEMS applications, consumers can participate in improving the quality of power systems. This study will discuss about the development of HEMS in associated with smart grid technology particularly the role of HEMS application with its DSM (Demand Side Management) and PEV (Plug-in Electric Vehicles) programs in the smart grid scheme to improve quality of power systems. Several studies have shown that the contribution of HEMS to the smart grid system can improve the power losses and voltage profile.

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3.1 Proposed Methodology

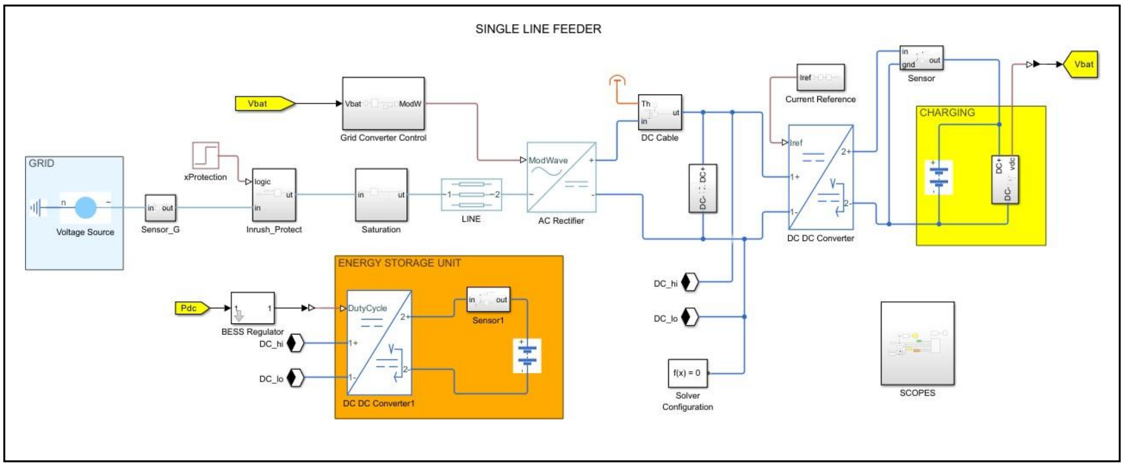

Figure 1: Single Line Feeder

Single Line Feeder: The role played by in-rush and transient currents on the grid transformeris captured.

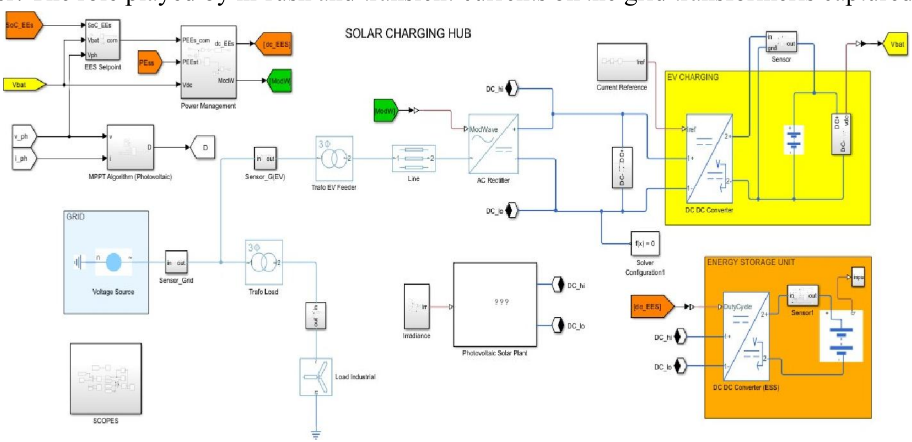

Figure 2: Solar Charging Hub

Solar Charging Hub: this model showcases the strength of sim scape to evaluate a concept forEV charging based on photovoltaic solar energy

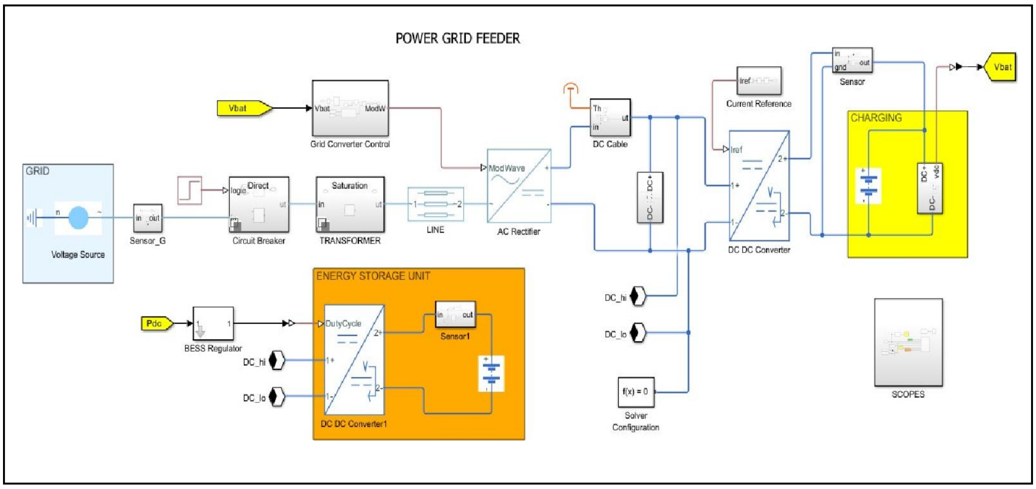

Figure 3: Power Grid Feeder

Power Grid Feeder: regulation of absorbed grid power for an EV charging event.

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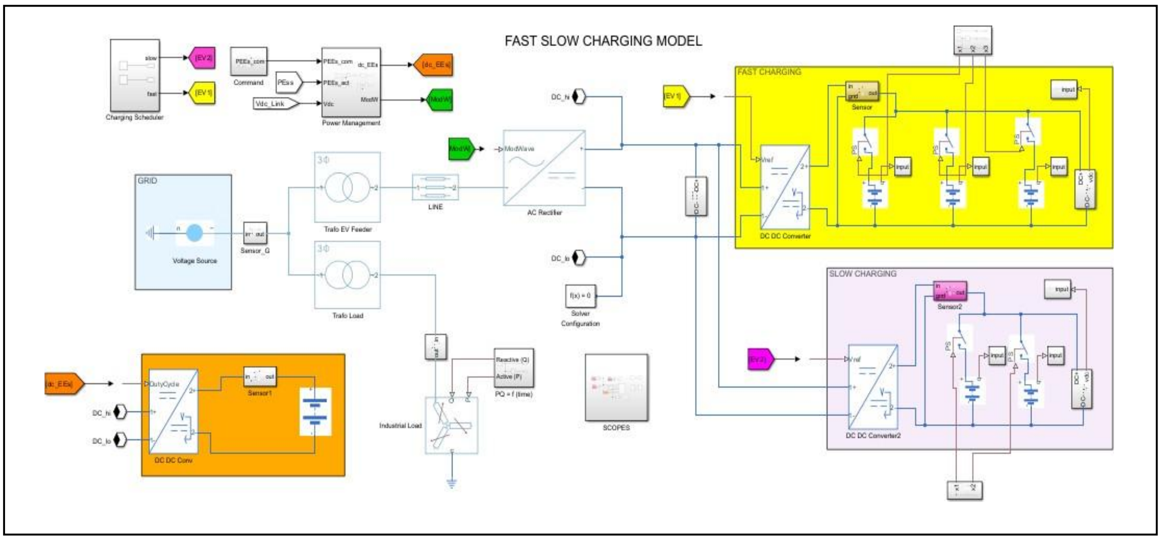

Figure 4: Fast Slow Charging Model

Fast Slow Charging Model: studies the overlapping effect of fast and slow charging on the grid. The benefits of peak shaving with the energy storage unit are encapsulated.

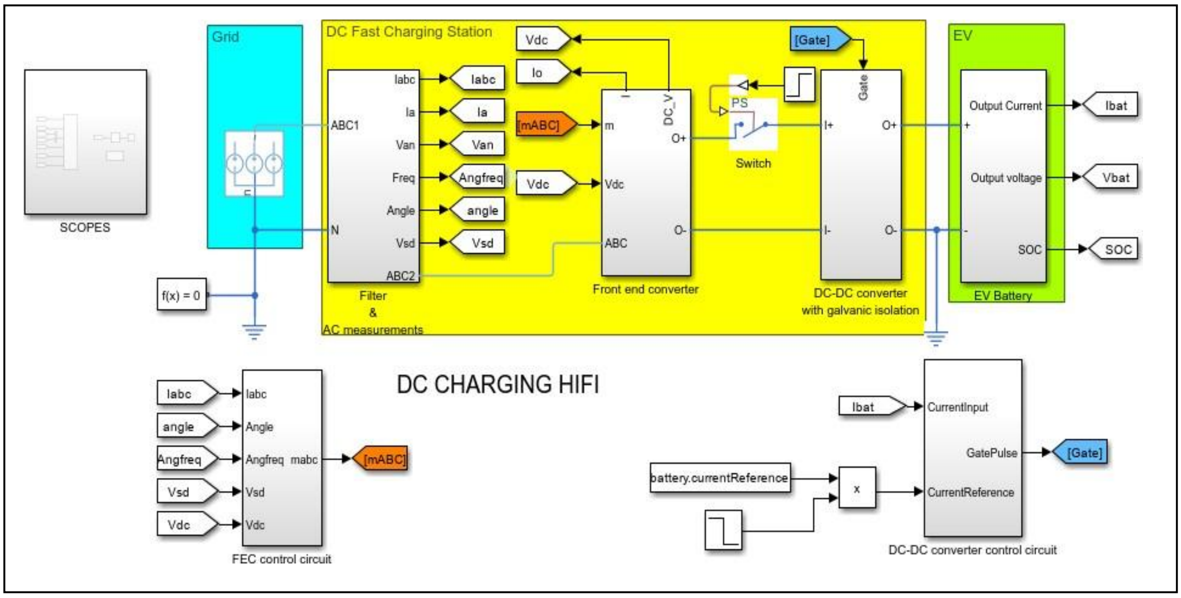

Figure 5: DC Charging HiFi

DC Charging HiFi: representation of a power conversion chain with switching DC-DC and AC-DC converters. Harmonic Analysis Possible.

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3.2 Flowchart

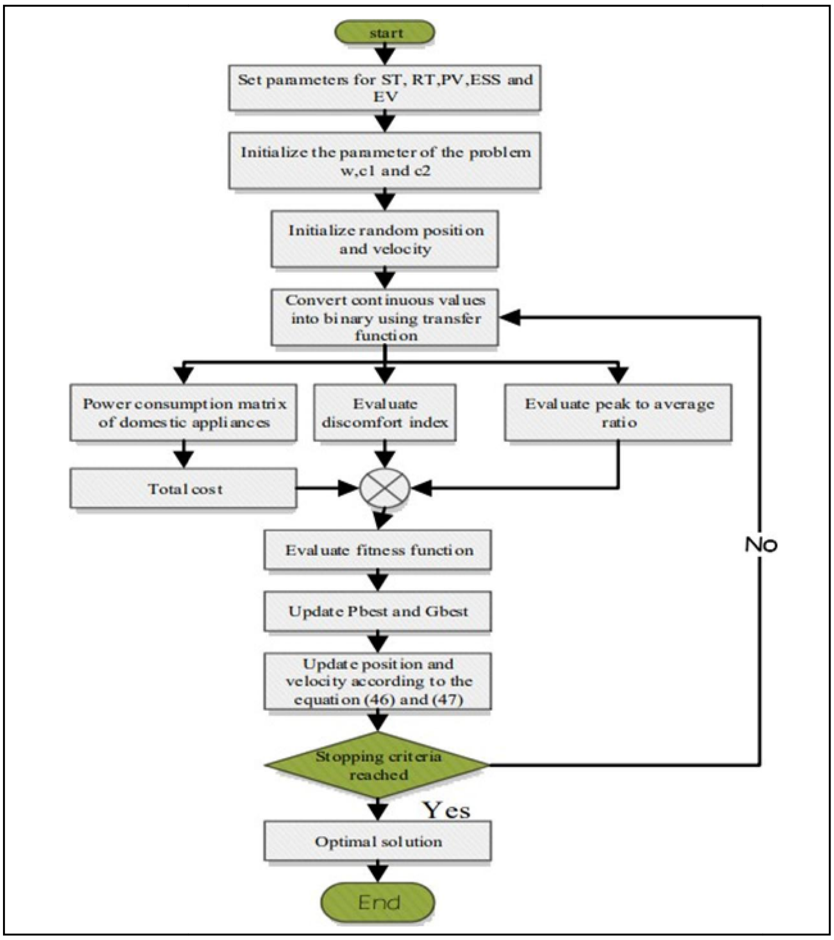

Figure 6: Flow chart

3.2 System Architecture / Block Diagram

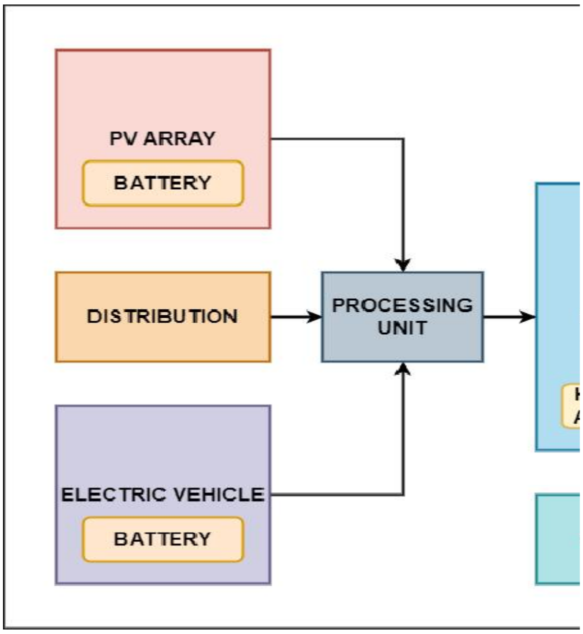

Figure 6: System Architecture / Block Diagram

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IV. CONCLUSION & FUTURE SCOPE

The contribution of HEMS application to the smart grid scheme in improving the power system reliability is conducted through demand side management (DSM) program. DSM implements one of them with demand response and improved system power reliability. Penetration of electric vehicles in the smart grid scheme can also improve the reliability of power systems through V2G and G2V. When the electric vehicle is at home then HEMS application will handle the mechanism of V2G or G2V. Contribution of HEMS to the smart grid system can improve the power losses and voltage profile; one of the studies showed that voltage fluctuations resulting from large disturbances can be reduced up to five times. Also, PV and ESS are taken into consideration in the project

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