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ELECTRIC VEHICLES LOAD MANAGEMENT IN SMART GRIDS USING DEMAND SIDE MANAGEMENT

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Abstract: The shift of transportation technology from internal combustion engine (ICE) based vehicles to electric vehicles (EVs) in recent times due to their lower emissions, fuel costs, and greater efficiency has brought EV technology to the forefront of the electric power distribution systems due to their ability to interact with the grid through vehicle-to-grid (V2G) infrastructure. The greater adoption of EVs presents an ideal use-case scenario of EVs acting as power dispatch, storage, and ancillary service-providing units. This EV aspect can be utilized more in the current smart grid (SG) scenario by incorporating demand-side management (DSM) through EV integration. The integration of EVs with DSM techniques is hurdled with various issues and challenges addressed throughout this review. As the use of electric vehicles (EVs) increases, managing their impact on the power grid becomes increasingly important. Smart grid technologies offer a solution to this problem, with demand side management (DSM) being a key approach. DSM involves managing the demand for electricity on the grid, incentivizing customers to reduce their usage during peak periods. In the context of EVs, DSM can be used to manage the charging of these vehicles during off-peak periods when the demand for electricity is lower. Additionally, Electric Vehicle (EV) batteries can be utilized as potential energy storage devices in micro-grids. They can help in micro-grid energy management by storing energy when there is surplus (Grid-To-Vehicle, G2V) and supplying energy back to the grid (Vehicle-To-Grid, V2G) when there is demand for it & helping to balance the grid and reduce demand. These DSM techniques can help to ensure that the power grid is able to handle the additional demand from EVs while maintaining stability and reliability. Overall, DSM in smart grids is an essential tool for managing the load of EVs and creating a more sustainable and efficient power grid.

***Keywords* -** **Inverter Circuit, DC Charger, Battery.**

INTRODUCTION

Electric vehicles (EVs) are becoming increasingly popular as a means of transportation, and as a result, they are placing additional demands on the power grid. To ensure that the power grid can handle these demands, smart grid technologies are being developed that can manage the load of EVs through demand-side management (DSM).

Demand-side management involves using a variety of techniques to manage the demand for electricity on the grid. One of the most effective techniques is to incentivize customers to reduce their electricity usage during peak demand periods. This can be achieved by offering financial incentives, such as lower electricity rates or rebates, for customers who reduce their usage during peak periods.

In the context of EVs, DSM can be used to manage the charging of EVs so that they are charged during off-peak periods when the demand for electricity is lower. This can be achieved through the use of smart charging technologies that allow EVs to be charged at a slower rate during peak periods and at a faster rate during off-peak periods.

Another approach to EV load management is vehicle-to-grid (V2G) technology. This technology enables EVs to not only draw electricity from the grid but also to feed electricity back into the grid when the demand is high. V2G technology can be used to help balance the grid during peak periods by reducing the demand for electricity and providing additional capacity to the grid.

Overall, the use of DSM techniques in managing the load of EVs in smart grids can help to ensure that the power grid is able to handle the additional demand from these vehicles while maintaining grid stability and reliability. By incentivizing customers to reduce their usage during peak periods and using V2G technology, DSM can help to create a more sustainable and efficient power grid.

LITERATURE SURVEY

There has been a significant amount of research conducted on electric vehicles (EVs) load management in smart grids using demand side management (DSM).

1. **"Demand-side management of electric vehicles in smart grids: A review by Zhe Jiang and Jianzhong Wu (2014)** - The article provides an overview of the integration of electric vehicles (EVs) into smart grids and how demand-side management can be used to optimize their use. The authors first introduce the concept of a smart grid, which is an advanced electricity network that uses communication and information technology to improve the efficiency, reliability, and sustainability of energy supply. They then discuss the integration of EVs into smart grids and how this integration can lead to both benefits and challenges. One major benefit of integrating EVs into smart grids is the potential to balance the load on the grid. Since EVs are typically charged at night, they can help to reduce peak demand during the day, which can help to prevent blackouts and reduce the need for new power plants. Additionally, EVs can be used to store excess renewable energy, such as solar or wind power, which can be used during times of high demand. The authors review various demand-side management techniques that can be used to optimize EV charging. These include time-of-use pricing, which incentivizes EV owners to charge their vehicles during off-peak hours when

electricity prices are lower; load shedding, which involves reducing the charging rate or stopping the charging of EVs during times of high demand on the grid; and vehicle-to-grid (V2G) technology, which allows EVs to discharge electricity back into the grid during times of high demand.

2. **"Electric vehicles and demand side management: A review of the technologies and the research trends" by Mingming Liu et al. (2017)** - The article provides a comprehensive review of the integration of electric vehicles (EVs) into demand side management (DSM) systems and the technologies that are being developed to enable this integration. The authors review various technologies that are being developed to enable the integration of EVs into DSM systems. These include vehicle-to-grid (V2G)
technology, which allows EVs to discharge electricity back into the grid during times of high demand; bidirectional charging technology, which allows EVs to both charge and discharge electricity and smart charging technology, which enables EV charging to be scheduled and controlled in response to changes in electricity demand and pricing. The authors also review the research trends in the field of EV-DSM integration, including the development of advanced algorithms and control systems to optimize EV charging and discharging, the use of big data analytics to predict electricity demand and optimize DSM strategies, and the integration of EVs into microgrid systems. Overall, the article provides a detailed overview of the technologies and research trends in the field of EV-DSM integration. The authors highlight the importance of this integration in enabling the transition to a more sustainable and efficient power grid.

3. **"Demand side management of electric vehicles in smart grids: A review of methods, models, and research directions" by Hao Zhu et al. (2018) -** The article provides a comprehensive review of the methods, models, and research directions in the field of the methods, models, and research directions in the field of demand-side management (DSM) of electric vehicles (EVs) in smart grids. The author first introduces the concept of DSM, which involves managing electricity demand in order to improve the efficiency, reliability, and sustainability of the power grid They then discuss the integration of EVs into DSM systems and the potential benefits of this integration, including the ability to balance the load on the grid and increases the use of renewable energy sources. And review various methods that have been proposed for managing EV charging in smart grids, including time-of-use pricing, load shedding, and vehicle-to-grid (V2G) technology They also discuss the various models that have been developed to analyze and optimize EV-DSM systems, including mathematical models, simulation models, and optimization models. then discuss the research directions in the field of EV-DSM integration. They highlight the importance of developing advanced algorithms and control systems to optimize EV charging and discharging, as well as the need for more research on the impacts of EV-DSM systems on the power grid and on EV owners. Overall, the article provides a detailed overview of the methods, models, and research directions in the field of EV-DSM integration. The authors emphasize the importance of this integration in enabling the transition to a more sustainable and efficient power grid.

4. **"A review of electric vehicle demand side management in smart grids" by Wasiu Popoola et al. (2020) –** The article provides a comprehensive review of the state of the art in the field of demand-side management (DSM) of electric vehicles (EVs) in smart grids. Firstly, introduce the concept of DSM, which involves managing electricity demand in order to improve the efficiency, reliability, and sustainability of the power grid. They then discuss the integration of EVs into DSM systems and the potential benefits of this integration, including the ability to balance the load on the grid and increase the use of renewable energy sources. The authors review various methods that have been proposed for managing EV charging in smart grids, including time-of-use pricing, load shedding, and vehicle-to-grid (V2G) technology. They also discuss the various challenges associated with EV-DSM systems, such as the need for accurate demand forecasting, the need for reliable communication and control systems, and the need to balance the interests of EV owners, utility companies, and the power grid as a whole. then review the various models that have been developed to analyse and optimize EV-DSM systems, including mathematical models, simulation models, and optimization models. They also discuss the various technologies that are being developed to enable the integration of EVs into DSM systems, including smart charging infrastructure and V2G technology. Finally, the authors discuss the research directions in the field of EV-DSM integration, including the need for more research on the impacts of EV-DSM systems on the power grid and on EV owners, as well as the need for more research on the development of advanced algorithms and control systems to optimize EV charging and discharging. Overall, the article provides a comprehensive review of the state of the art in the field of EV-DSM integration.

Overall, these studies suggest that DSM is a promising approach for managing the load of EVs in smart grids, but more research is needed to address the challenges associated with its implementation. The use of V2G technology and the development of interoperable DSM systems are likely to be key areas of focus for future research.

PROBLEM STATEMENT

- Electric vehicles hold great promise to replace ICEVS affordably for a number of on-road applications and the increased number of electric vehicle has lots of negative effects on the grid such as increased peak demand as well as lowered household voltages.
- And EV owners are experiencing chronic problems with time for full charging of EV batteries.

OBJECTIVES

- To reduce the dependency on power grid for charging electric vehicle.
- To reduce the time required for complete charge of EV battery.

METHODOLOGY

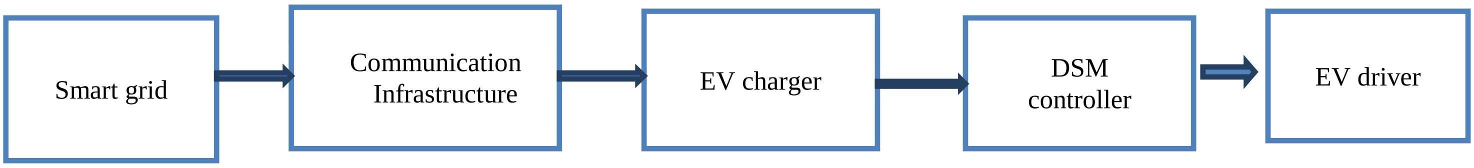


Fig. Block diagram

The smart grid is responsible for managing the supply and demand of electricity on the grid. It communicates with the Communication Infrastructure, which provides real-time information on electricity prices and grid capacity. The EV Charger is responsible for charging the electric vehicle and communicates with the DSM Controller to receive instructions on when to charge the vehicle. The DSM Controller is responsible for managing the load on the grid by communicating with the Smart Grid and the EV Charger. It receives real-time information on electricity prices and grid capacity from the Communication Infrastructure and uses this information to determine when to instruct the EV Charger to charge the vehicle. The DSM Controller can also implement TOU pricing or DLC to incentivize EV owners to charge their vehicles during off-peak periods. Finally, the EV Driver is responsible for plugging in the vehicle and following the instructions provided by the EV Charger and the DSM Controller.

Overview of DSM Techniques

DSM is an initiative implemented by electricity utilities to encourage consumers to adopt procedures and practices that are advantageous to both parties. These practices include any activity that aims to change load shapes by influencing the electricity consumption behavior ofconsumers. Notably, the implementation of

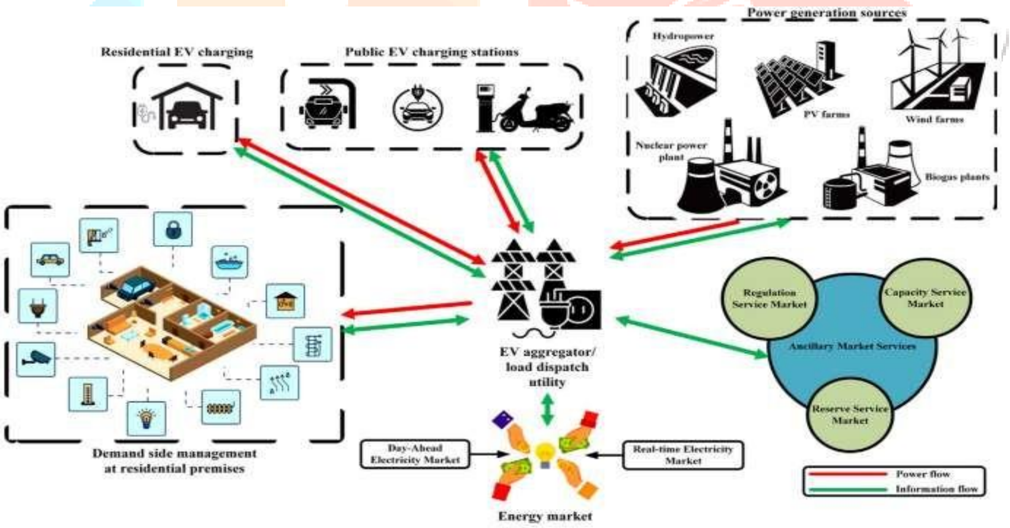


Fig. EV operation in overall smart grid scenario with participation in electricity markets

DSM increases the complexity of existing power systems because the adequate performance of DSM requires monitoring power system loads and generators. Consequently, the deployment of sensors, the provision of incentives to participants of DSM programs and the performance of the general activities of DSM will incur additional expenditures. However, as we will later elucidate in Section, the benefits of DSM far outweigh its drawback of increased power system cost. Figure 1 shows that DSM consists of energy efficiency, demand response and strategic load growth. Demand response is normally performed through peak clipping, valley filling or load-shifting activities or any combination of these techniques. Demand response is also known as flexible load shape because of the flexibility exhibited by the activities.

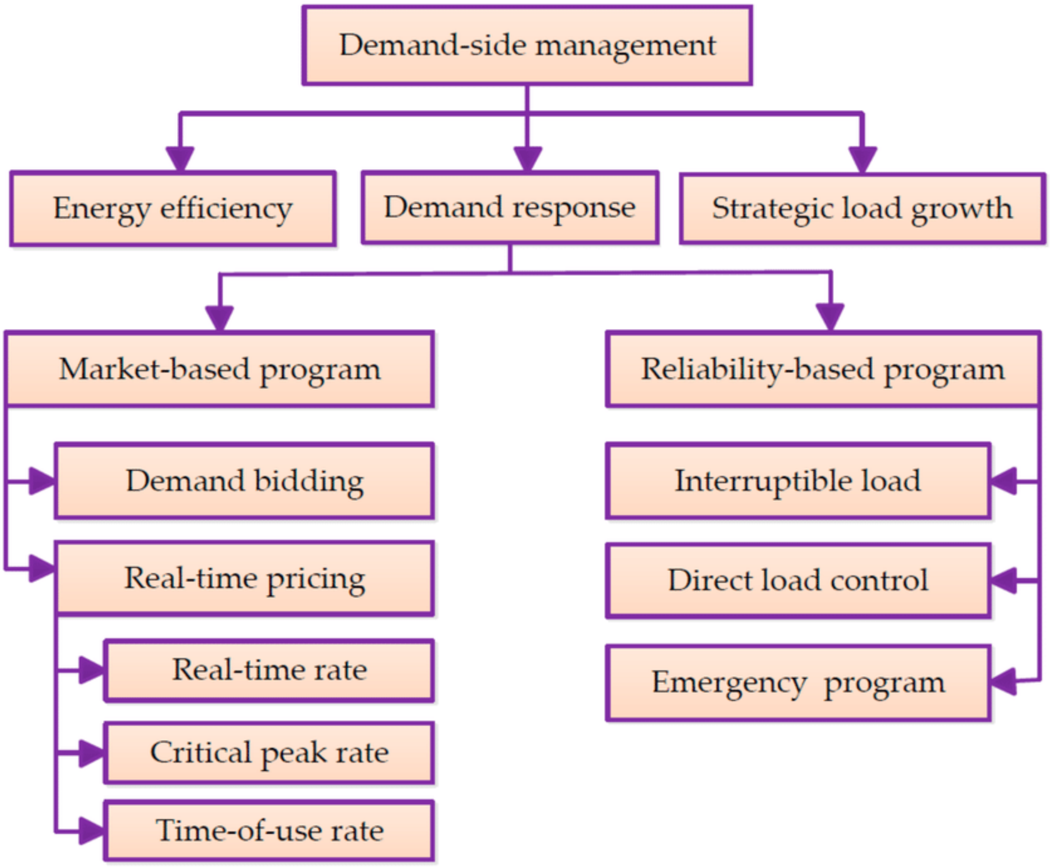


Fig. Various demand side management techniques

HARDWARE SPECIFICATION

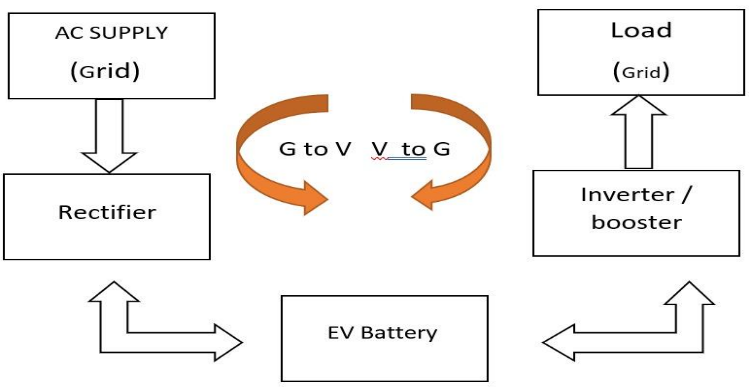


Fig. Block diagram of electric vehicles load management in smart grid

SOFTWARE SPECIFICATION

MATLAB

Introduction to MATLAB:

MATLAB is a high-performance language for technical computing. The name mat lab stands for matrix laboratory. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

Strengths of MATLAB:

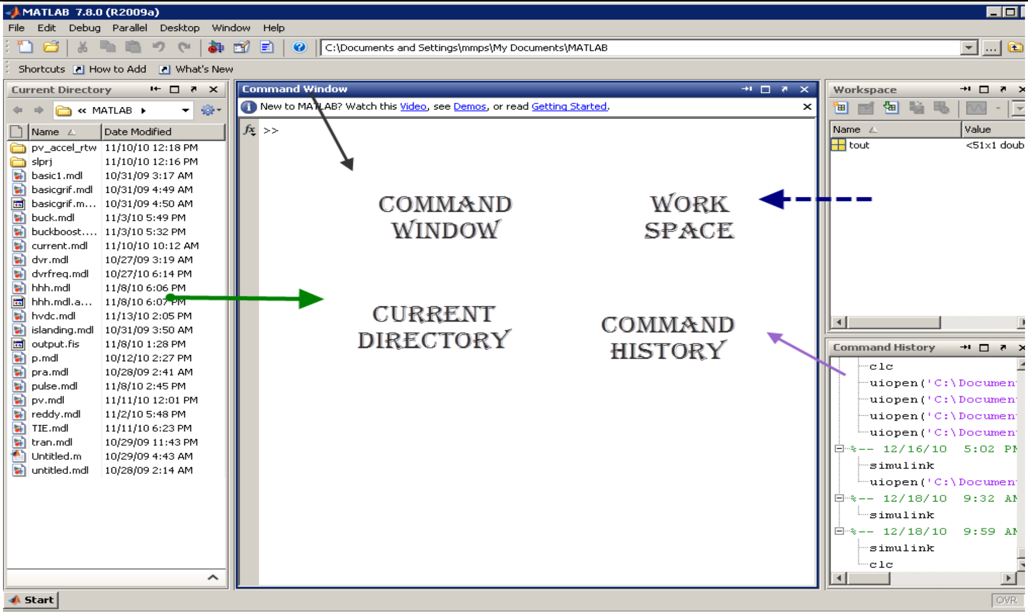
- MATLAB is relatively easy to learn.
- MATLAB code is optimized to be relatively quick when performing matrix operations.
- MATLAB may behave like a calculator or as a programming language.
- MATLAB is interpreted, errors are easier to fix.
- Although primarily procedural, MATLAB does have some object-oriented elements.

Other features:

- 2-D and 3-D graphics functions for visualizing data
- Tools for building custom graphical user interfaces.
- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, FORTRAN, Java, COM, and Microsoft Excel.

Components of MATLAB:

- Workspace
- Current Directory
- Command History
- Command Window



Block diagram of Mat lab components

MATLAB and engineering:

MATLAB was first adopted by researchers and practitioners in control engineering, little's specialty, but quickly spread to many other domains. It is now also used in education, in particular the teaching of linear algebra and numerical analysis and is popular amongst scientists involved in image processing. However, many researchers, mostly from Computer Science background feel that MATLAB should be used only for mathematical analysis necessary in image processing and not for implementation of image processing software. Moreover, MATLAB should not be used to simulate computer architectures, systems software, and computer networks unless it is while solving some numeric problem.

Toolboxes in MATLAB:

- Simulink
- Fuzzy
- Genetic algorithm
- Neural network
- Wavelet

SIMULINK

Introduction:

Simulink is a software add-on to mat lab which is a mathematical tool developed by The Math works, (http://www.mathworks.com) a company based in Natick. Mat lab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries. Various toolboxes for different techniques, such as Fuzzy Logic, Neural Networks, DSP, Statistics etc. are available with Simulink, which enhances the processing power of the tool. The main advantage is the availability of templates / building blocks, which avoid the necessity of typing code for small mathematical processes.

Concept of signal and logic flow:

In Simulink, data/information from various blocks are sent to another block by lines connecting the relevant blocks. Signals can be generated and fed into blocks dynamic / static). Data can be fed into functions. Data can then be dumped into sinks, which could be scopes, displays, or could be saved to a file. Data can be connected from one block to another, can be branched, multiplexed etc. In simulation, data is processed and transferred only at discrete times, since all computers are discrete systems. Thus, a simulation time step (otherwise called an integration time step) is essential, and the selection of that step is determined by the fastest dynamics in the simulated system.

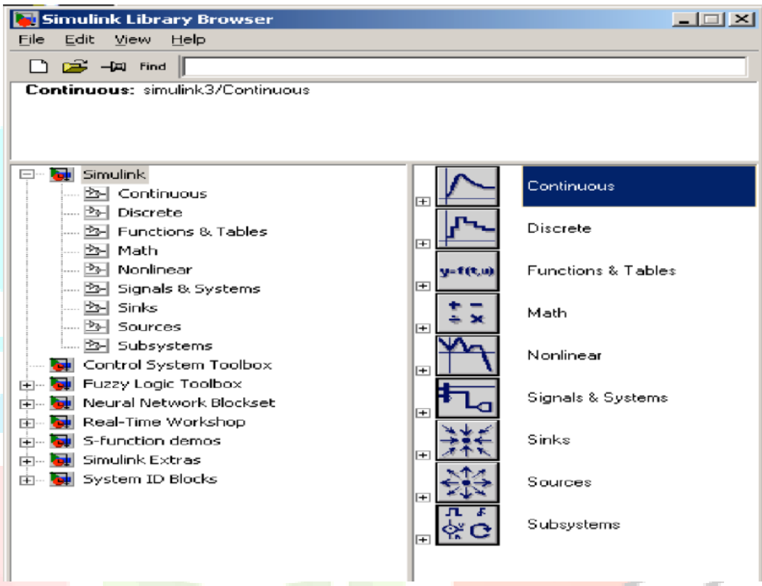


Fig 4.1 Simulink library browser

Connecting blocks:

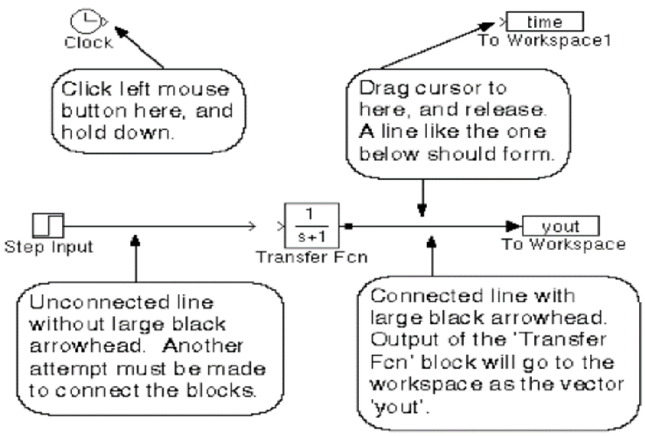


Fig. Connecting blocks.

To connect blocks, left click and drag the mouse from the output of one block to the input of another block.

Sources and sinks:

The sources library contains the sources of data/signals that one would use in a dynamic system simulation. One may want to use a constant input, a sinusoidal wave, a step, a repeating sequence such as a pulse train, a ramp etc. One may want to test disturbance effects and can use the random signal generator to simulate noise. The clock may be used to create a time index for plotting purposes. The ground could be used to connect to any unused port, to avoid warning messages indicating unconnected ports.

The sinks are blocks where signals are terminated or ultimately used. In most cases, we would want to store the resulting data in a file, or a matrix of variables. The data could be displayed or even stored to a file. The stop block could be used to stop the simulation if the input to that block (the signal being sunk) is non-zero. Figure 3 shows the available blocks in the sources and sinks libraries. Unused signals must be terminated, to prevent warnings about unconnected signals.

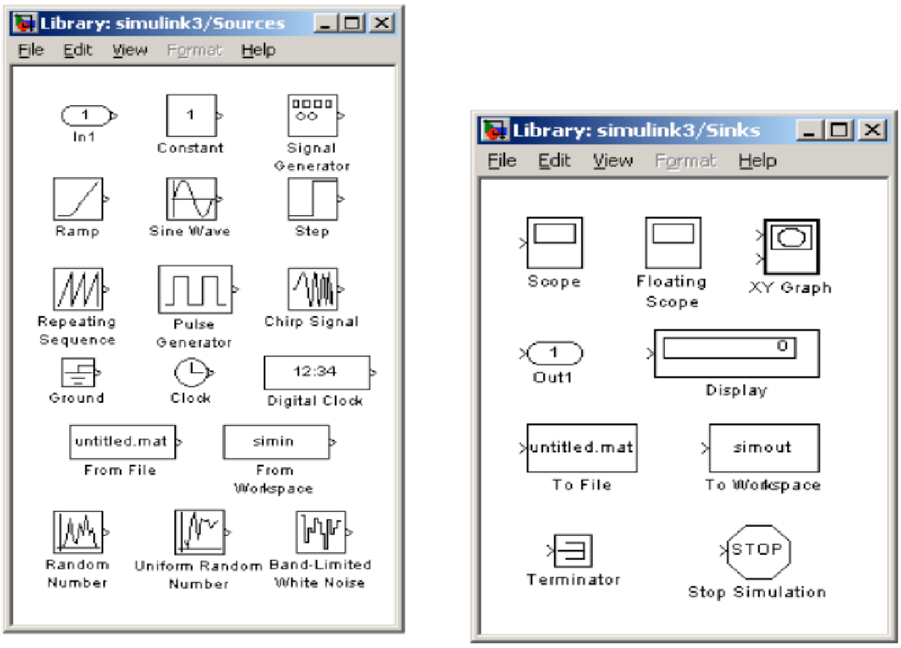


Fig. Sources and sinks

Continuous and discrete systems:

All dynamic systems can be analyzed as continuous or discrete time systems. Simulink allows you to represent these systems using transfer functions, integration blocks, delay blocks etc.

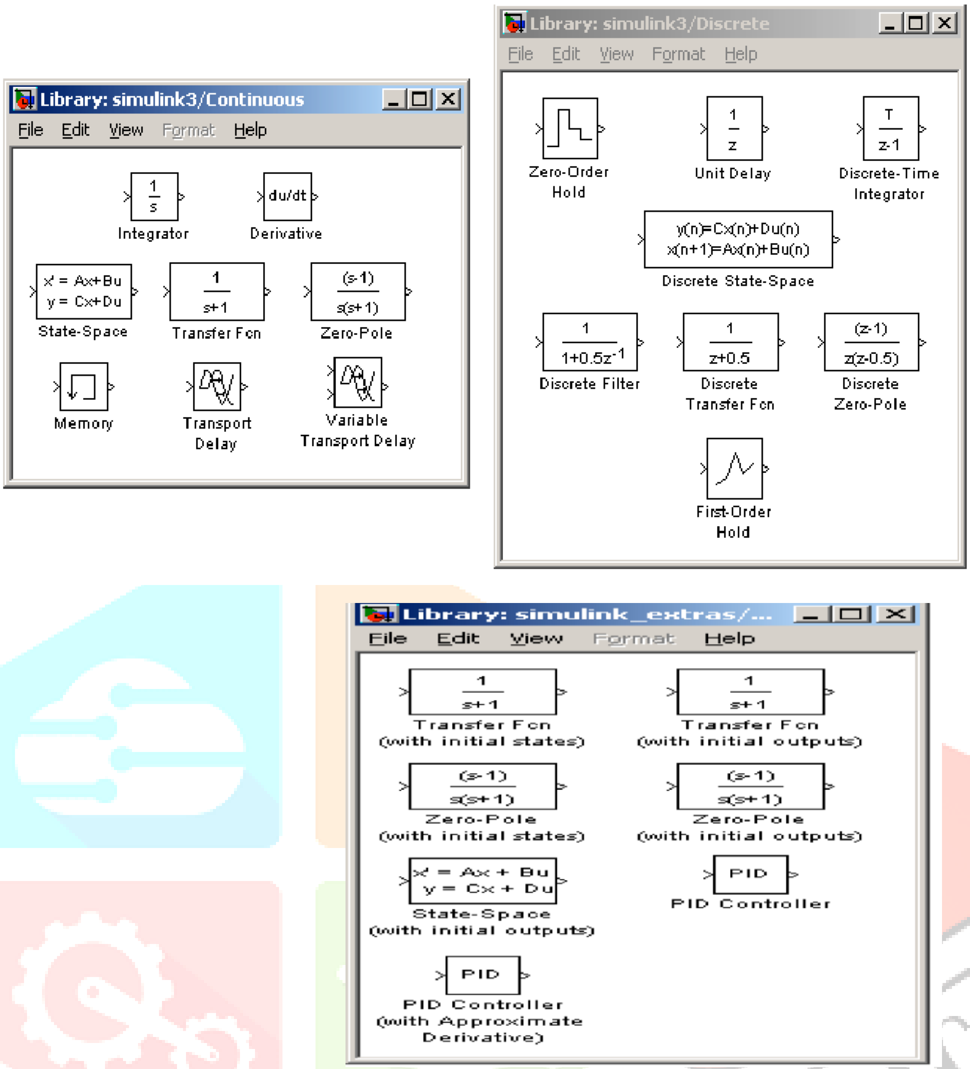


fig 4.4 continuous and discrete systems

Non-linear operators:

A main advantage of using tools such as Simulink is the ability to simulate non-linear systems and arrive at results without having to solve analytically. It is very difficult to arrive at an analytical solution for a system having non-linearities such as saturation, signup function, limited slew rates etc. In Simulation, since systems are analyzed using iterations, non-linearities are not a hindrance. One such could be a saturation block, to indicate a physical limitation on a parameter, such as a voltage signal to a motor etc. Manual switches are useful when trying simulations with different cases. Switches are the logical equivalent of if-then statements in programming.

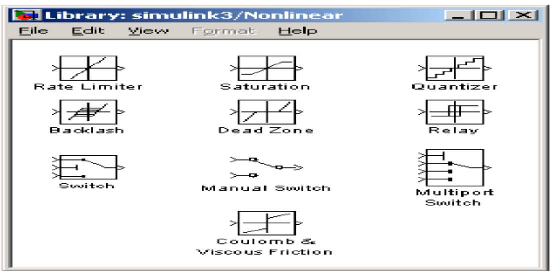


fig 4.5 Simulink blocks

Mathematical operations:

Mathematical operators such as products, sum, logical operations such as and, or, etc. can be programmed along with the signal flow. Matrix multiplication becomes easy with the matrix gain block. Trigonometric functions such as sin or tan inverse (at an) are also available. Relational operators such as 'equal to', 'greater than' etc. can also be used in logic circuits

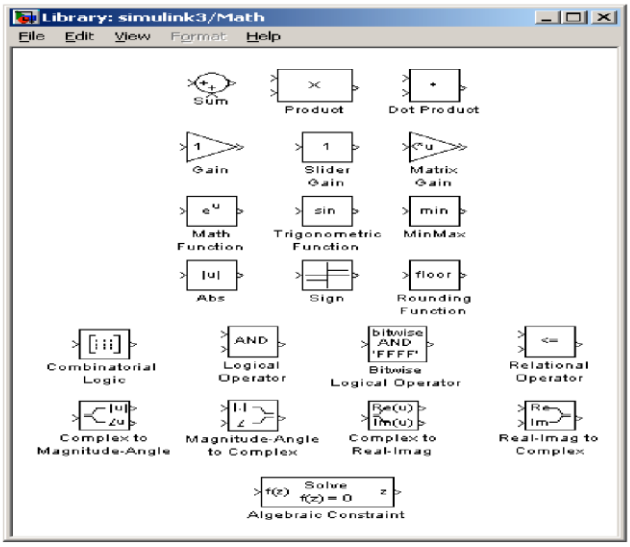


Fig 4.6 Simulink math blocks

Signals & data transfer:

In complicated block diagrams, there may arise the need to transfer data from one portion to another portion of the block. They may be in different subsystems. That signal could be dumped into a GOTO block, which is used to send signals from one subsystem to another.

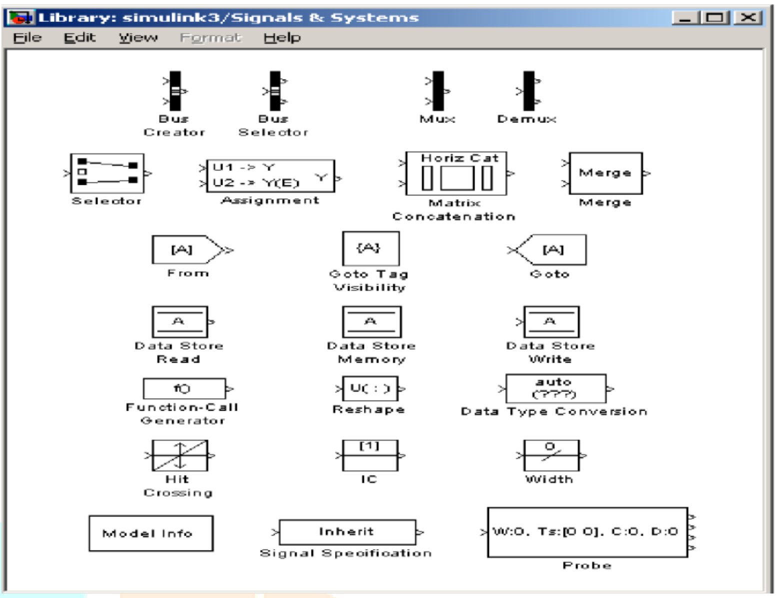


fig 4.7 signals and systems

Multiplexing helps us remove clutter due to excessive connectors and makes matrix (column/row) visualization easier.

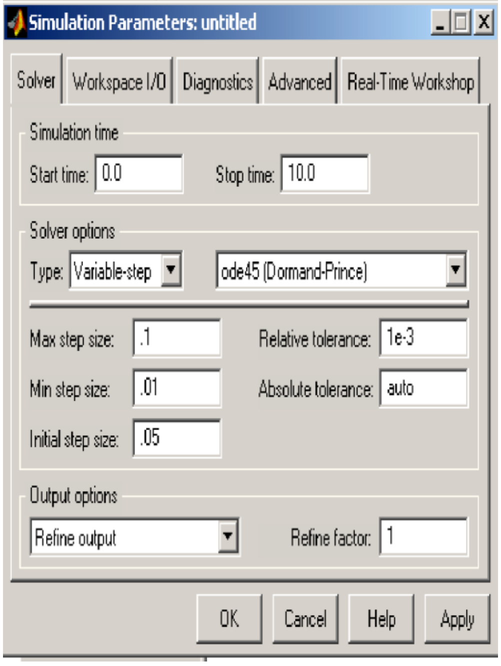
Making subsystems:

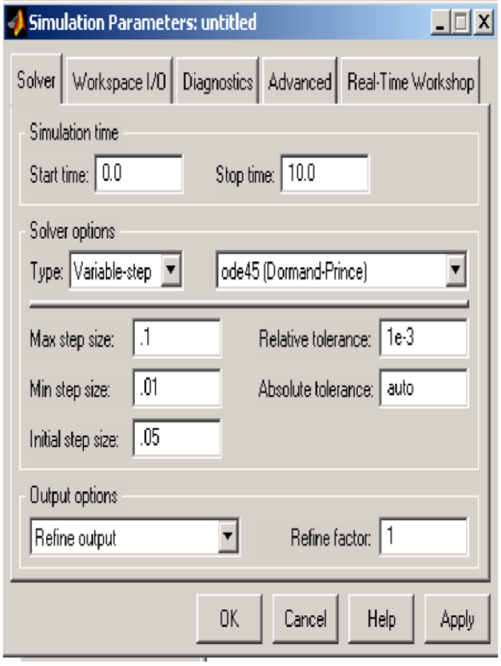
Drag a subsystem from the Simulink Library Browser and place it in the parent block where you would like to hide the code. The type of subsystem depends on the purpose of the block. In general, one will use the standard subsystem, but other subsystems can be chosen. For instance, the subsystem can be a triggered block, which is enabled only when a trigger signal is received.

Open (double click) the subsystem and create input / output PORTS, which transfer signals into and out of the subsystem. The input and output ports are created by dragging them from the Sources and Sinks directories respectively. When ports are created in the subsystem, they automatically create ports on the external (parent) block. This allows for connecting the appropriate signals from the parent block to the subsystem.

Setting simulation parameters:

Running a simulation in the computer always requires a numerical technique to solve a differential equation. The system can be simulated as a continuous system, or a discrete system based on the blocks inside. The simulation starts and stop time can be specified. In the case of variable step size, the smallest and largest step size can be specified. A Fixed step size is recommended, and it allows for indexing time to a precise number of points, thus controlling the size of the data vector. Simulation step size must be decided based on the dynamics of the system. A thermal process may warrant a step size of a few seconds, but a DC motor in the system may be quite fast and may require a step size of a few milliseconds.





Sim power system:

- Introduction:

SimPowerSystems software and other products of the Physical Modeling product family work together with Simulink software to model electrical, mechanical, and control systems.

SimPowerSystems software operates in the Simulink environment. Therefore, before starting this user's guide, make yourself familiar with Simulink documentation. Or, if you perform signal processing and communications tasks (as opposed to control system design tasks), see the Signal Processing Block set documentation.

The Role of Simulation in Design:

Electrical power systems are combinations of electrical circuits and electromechanical devices like motors and generators. Engineers working in this discipline are constantly improving the performance of the systems. Requirements for drastically increased efficiency have forced power system designers to use power electronic devices and sophisticated control system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation.

Land-based power generation from hydroelectric, steam, or other devices is not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives.

SimPowerSystems software is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. It uses the Simulink environment, allowing you to build a model using simple click and drag procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library.

Since Simulink uses the MATLAB computational engine, designers can also use MATLAB toolboxes and Simulink block sets. SimPowerSystems software belongs to the Physical Modeling product family and uses similar block and connection line interface.

Sim power systems Libraries:

SimPowerSystems libraries contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are proven ones coming from textbooks, and their validity is based on the experience of the Power Systems Testing and Simulation Laboratory of Hydro-Québec, a large North American utility located in Canada, and also on the experience of École de Technology Supérieure and Université Laval. The capabilities of SimPowerSystems software for modeling a typical electrical system are illustrated in demonstration files. And for users who want to refresh their knowledge of power system theory, there are also self-learning case studies.

The SimPowerSystems main library, powerlib, organizes its blocks into libraries according to their behavior. The powerlib library window displays the block library icons and names. Double-click a library icon to open the library and access the blocks. The main powerlib library window also contains the Power Gui block that opens a graphical user interface for the steady-state analysis of electrical circuits.

Nonlinear Simulink Blocks for Sim power systems Models:

The nonlinear Simulink blocks of the powerlib library are stored in a special block library named powerlib models. These masked Simulink models are used by SimPowerSystems software to build the equivalent Simulink model of your circuit. See Improving Simulation Performance for a description of the powerlib model's library.

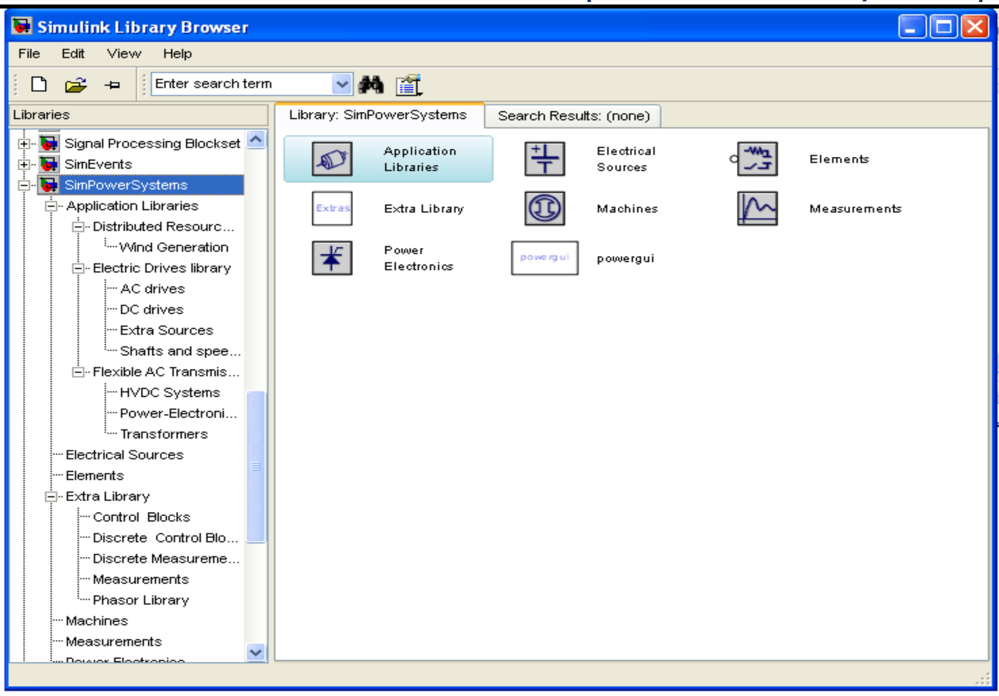


Diagram of Sim power system

Applications of MATLAB:

MATLAB is a data-manipulation software package that allows data to be analyzed and visualized using existing functions and user-designed programs. MATLAB is a numerical computing environment and programming language. MATLAB allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Although it specializes in numerical computing, an optional toolbox interfaces with the Maple symbolic engine, allowing it to be part of a full computer algebra system.

Some of the mat lab applications listed are:

- Orthogonal frequency division multiplexing
- Genetic algorithm data mining
- Speech recognition using VQ method.
- Channel Estimation and Detection in DS-CDMA
- Analysis of iterative channel estimation and multi-user detection in multi path DS-CDMA channels
- Time-domain signal detection
- Time-domain signal detection based on second-order statistics for mimo-OFDM systems
- Space–time block coding
- Space–time block codes for mimo channels
- Blind channel estimation

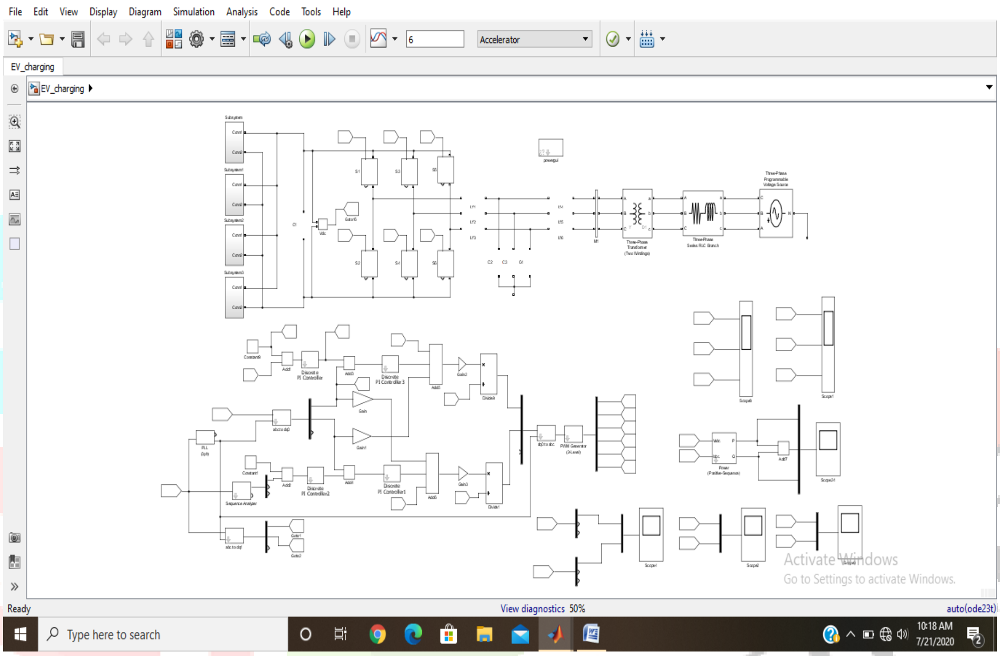
Basic circuit designing and analyzing of results:

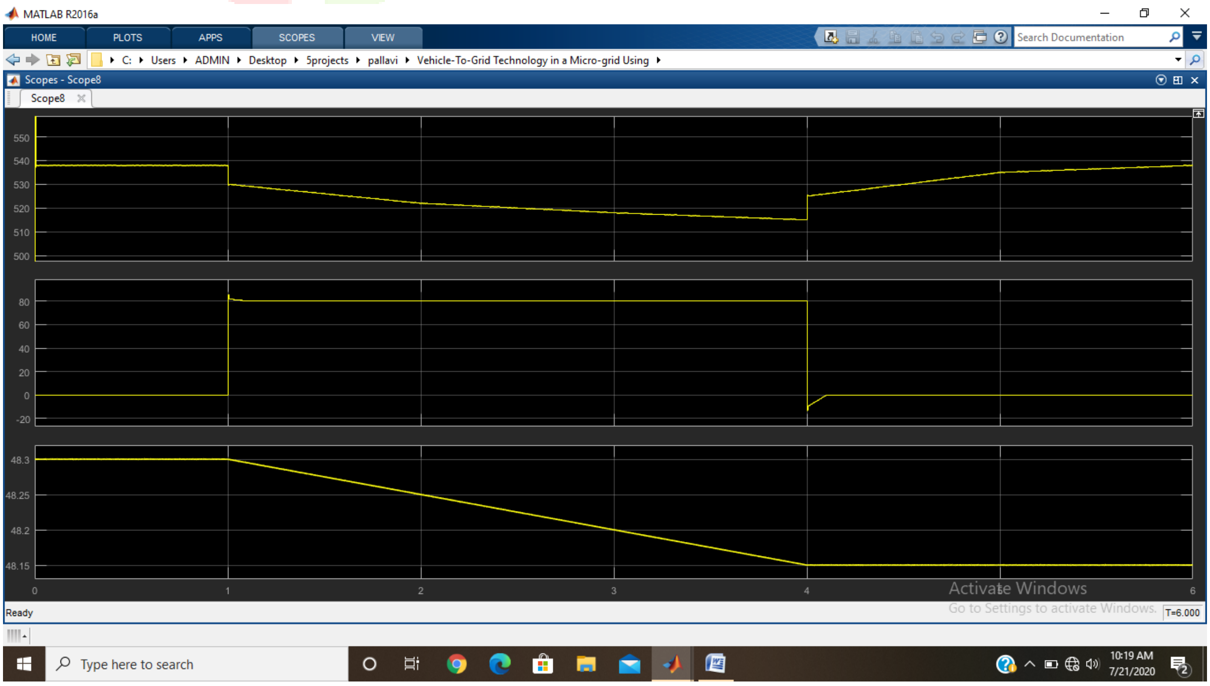
Click on the file and select new model file and a file will be appeared:

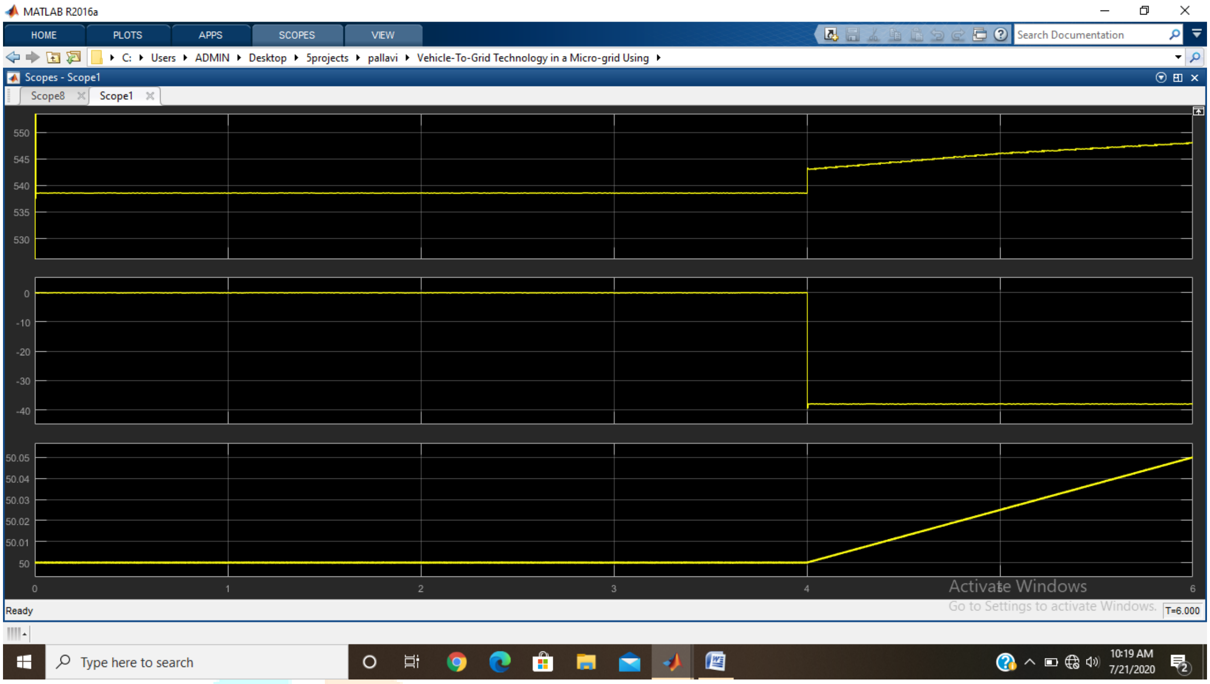
Now a block and right click on it, the block will be appearing in the new model file (untitled)

For example, consider a sine wave in the source block and in order to obtain or to view the output place the scope block. Join those two blocks. Now a simple circuit is ready, now set the simulation time in the tool bar (default it is set to 10.0), simulate the circuit by clicking on the simulation icon (PLAY BUTTON). Simulation is completed now by double clicking on the scope u can view the output, press the auto scale button and o/p will appear clearly.

RESULT AND DISCUSSION



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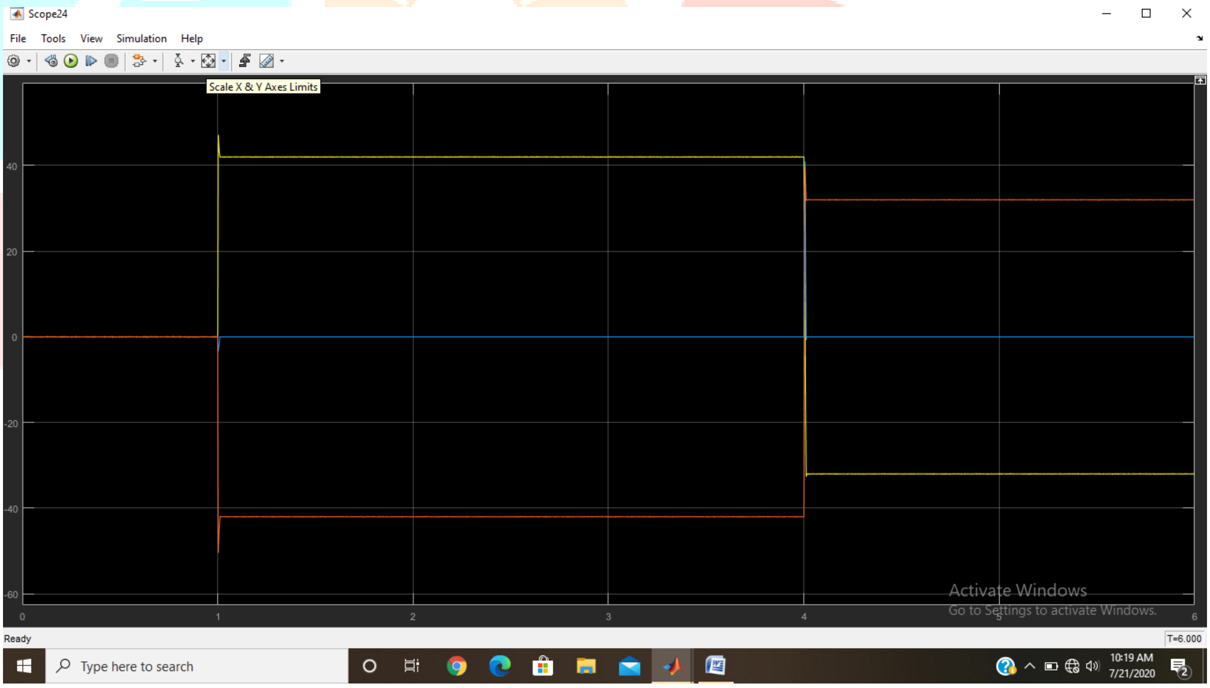
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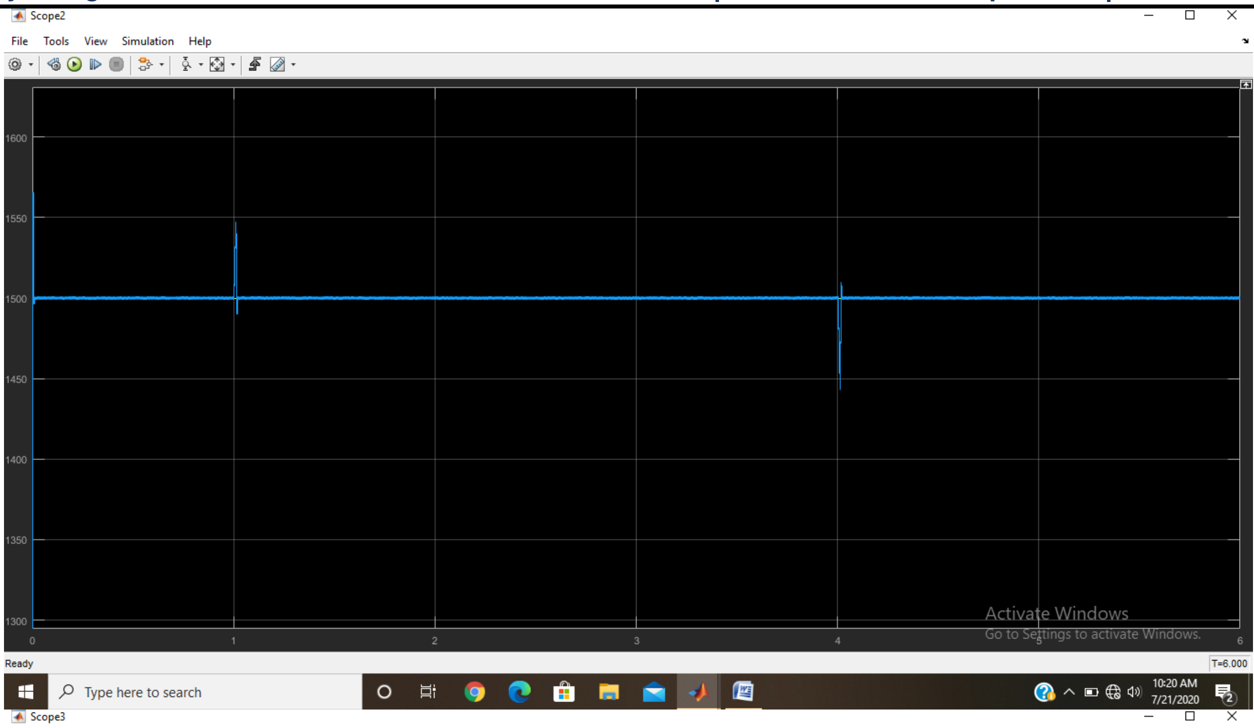


Fig. Reference current tracking by inverter controller

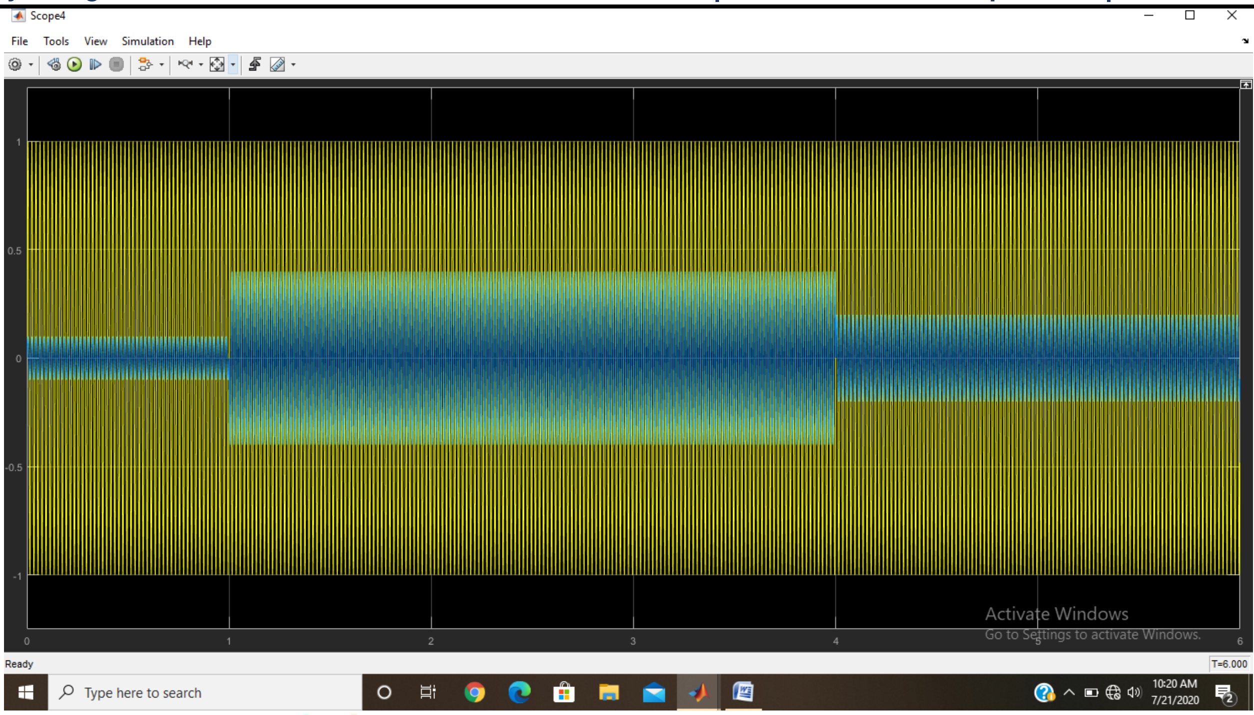
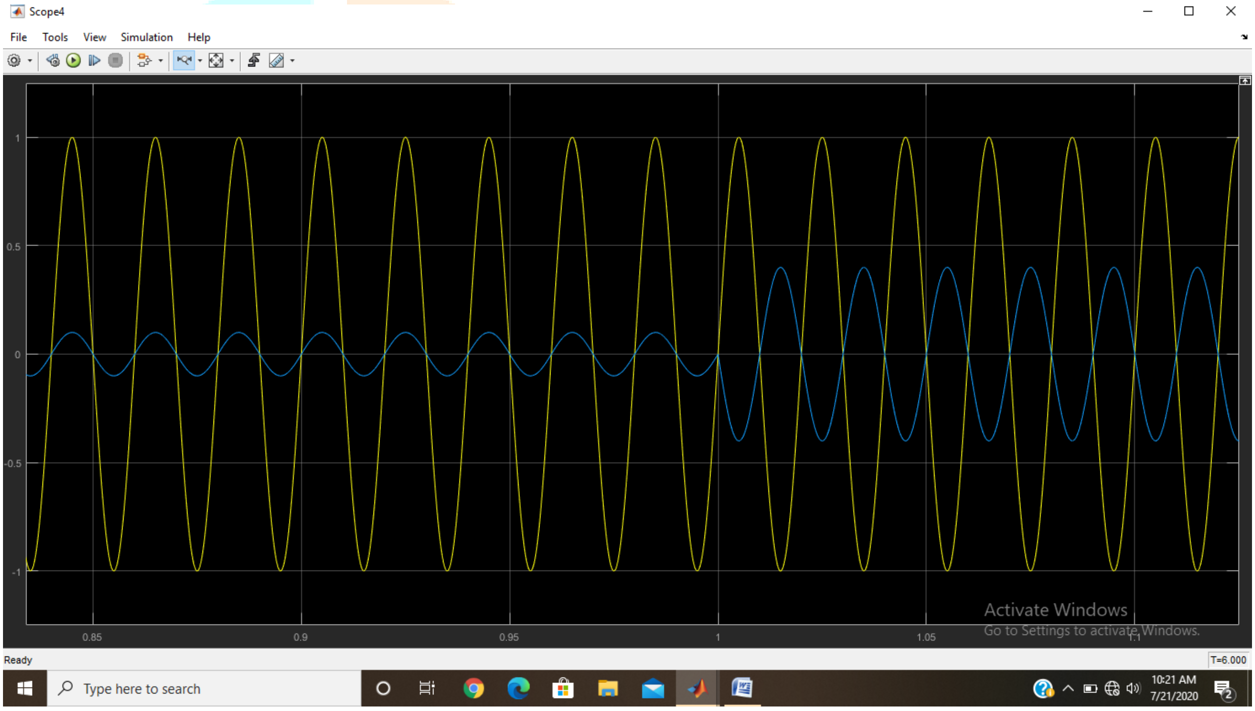


Fig. 11. Grid voltage and grid injected current during V2G-G2V operation



ADVANTAGES

ADVANTAGES

1. Reduced peak demand: DSM can help to reduce peak demand for electricity by incentivizing customers to shift their EV charging to off-peak periods. This can reduce the need for expensive infrastructure upgrades and increase grid stability and reliability.

2. Increased renewable energy integration: DSM can help to integrate renewable energy sources such as solar and wind power into the grid by aligning EV charging with the availability of these energy sources. This can help to reduce the need for energy storage and improve the overall sustainability of the power grid.

3. Reduced energy costs: DSM can help to reduce energy costs for customers by incentivizing them to shift their charging to off-peak periods when energy prices are lower.

4. Improved grid efficiency: DSM can help to optimize the use of existing grid infrastructure by reducing the need for costly upgrades and improving the overall efficiency of the power grid.

APPLICATIONS

1. Residential EV charging: DSM can be applied to residential EV charging by incentivizing customers to shift their charging to off-peak periods when the demand for electricity is lower.

2. Commercial EV charging: DSM can be applied to commercial EV charging by using load management techniques to balance the load across different charging stations and prevent overloading of the power grid.

3. Public EV charging: DSM can be applied to public EV charging by using load management techniques to balance the load across different charging stations and prevent overloading of the power grid.

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