# Effect of Non-conventional Loads on System Stability with different Control Strategies of Modern Smart Grid Centric System Dynamics


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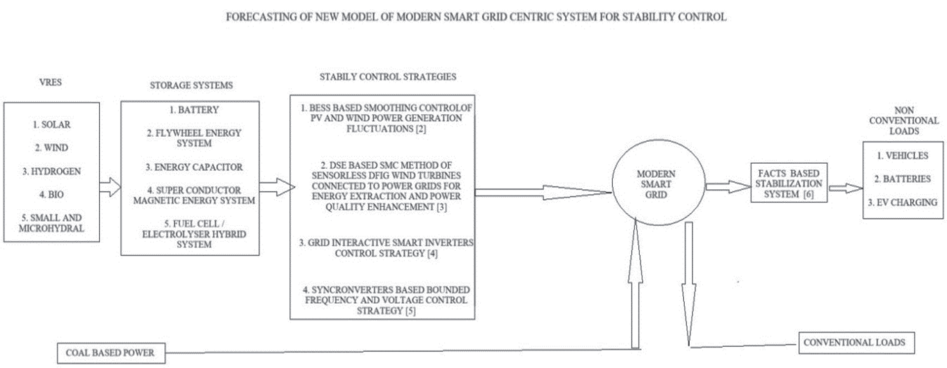
***Abstract*—In recent past, due to energy extraction from renewable resources exceeded churned out coal-based power, an emerging scenario developed to operate the smart grid without any excuse. In this term paper, a thorough study has been made to identify different system dynamics, their stability analysis with different emerging control strategies of modern smart grid. This term paper also shows the concept of integrated modern smart grid centric system and discusses recent real-life instances of phenomena/disturbance.**



***Keywords*— vandalism, participation factor, dumb charging, smart charging.**


## I. INTRODUCTION

The advancement of renewable generation is recent years have left an ineradicable impact on the electric energy market. According to the Electric Power Monthly (U.S.) [1], in April 2019, the amount of energy generated from renewable resources exceeded the total energy extracted from coal based powered plants for the first time. It is a land mark event to fulfil the world target to cut off the coal based powered plant for sustainable development with economic way within 2035. Fig. 1 presents a schematic representation of modern smart grid-centric system for optimal power system operation.




Forecasting of new model of modern smart grid centric system for stability control.

## II. RECENT MODERN SMART GRID SYSTEM DYNAMICS[1]

Major classification of recent (in 2022 and 2023) disturbances and unusual occurrences in modern smart grid centric system include complete loss of monitoring and control capabilities[2], islanding due to technical

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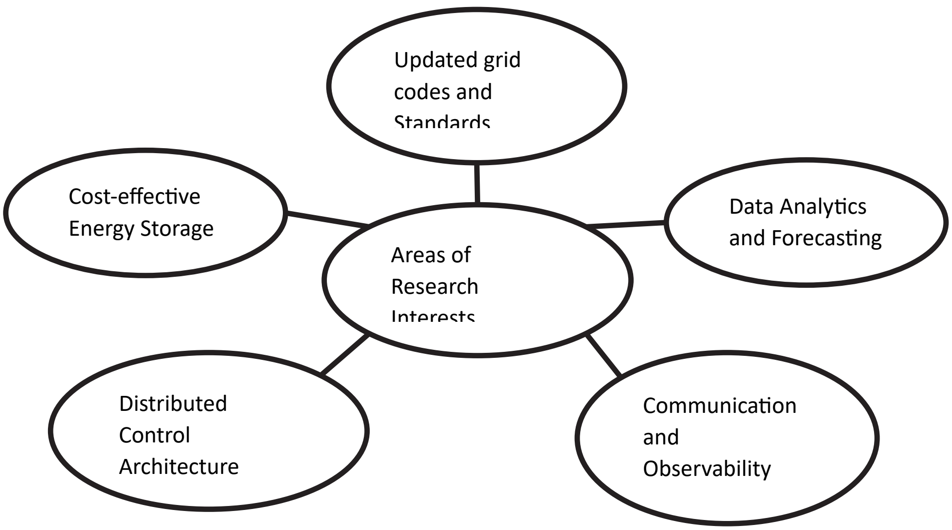
failure, physical threats due to natural weather-related issues. Failures due to deficiency of fuel supply and acts of vandalism have also been observed. The areas of research for integration of renewable sources are highlighted in Fig. 2. Technical issues faced with increased penetration of variable renewable energy resources can be summarised [3]-[6] as

- *Uncertainty of available energy:* Many resources like solar and wind vary regularly and have too supplemented by controllable sources or adequate storage. Proper usage of variable renewable resources requires forecasting of demand and resource.
- *Power system stability:* The system becomes more prone to disturbances with reduced inertia. The inverters interfacing the resources should be capable of controlling voltage, frequency, active and reactive power either in grid connected or islanded mode. Fault-ride-through capabilities are incorporated to increase the resilience of the system.
- *Protection coordination:* Lower short-circuit current levels due to limited current being supplied by the inverters require readjustment and newer protection schemes to be incorporated.
- *Unintentional islanding:* Several new techniques have been proposed to protect against unintentional islanding based on active, passive and hybrid technologies. Signal processing and artificial-intelligence based techniques have been able to provide required detection.
- *Black-start capability and distributed control [7]:* Greater penetration of variable resources requires the system to have the ability to restore operation following an outage. New distributed control architecture is necessary for proper coordination of the different resources.




Research needs in power system to achieve increased variable renewable resource integration

## III. Different Techniques/Strategies for System Stability at Grid Level

Decentralized charging of Plug-in Electric Vehicles (PEV) [8] and its impact on grid system dynamics is essential to be studied. Impact of PEVs on system dynamics can be divided into three main groups-

Impact that exploit the flexibility of PEVs to improve system dynamics.
Impact that explain the affect of large fleets of PEVs on the system dynamics and possibly lead to a collapse.
Impact of Electric Vehicles (EV) on dynamic frequency response [9].

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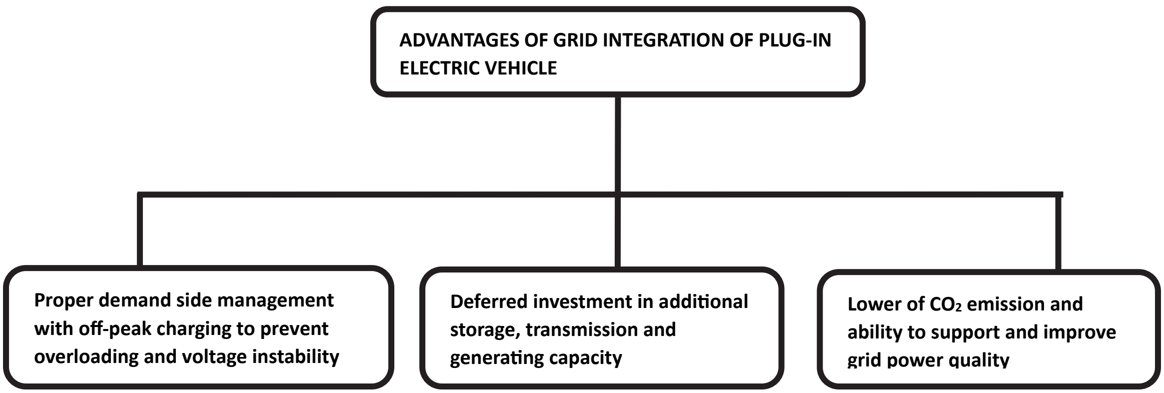
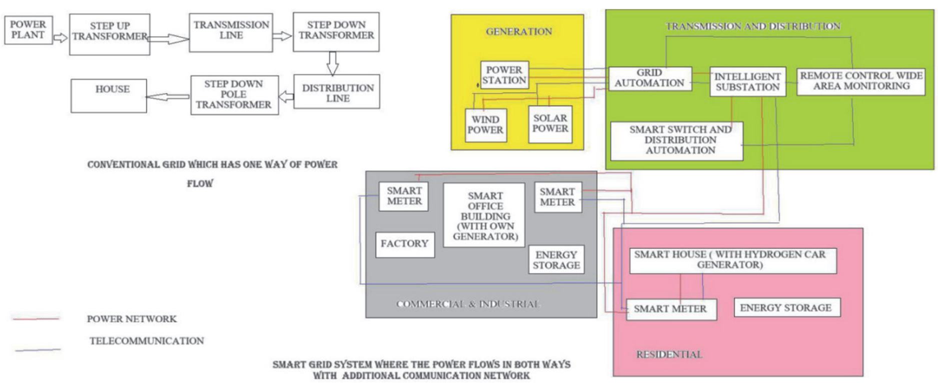
Smart charging of PEVs offer several advantages as shown in Fig. 3. Impact of EVs at a glance:

1) The EV aggregation has improves dynamic frequency response of the grid system. EVs are utilized to maintain the frequency stability. It can significantly reduce the deviations of the power curve during a particular day [10].
2) EVs help to improve demand-side management, specially in charging mode. With the application of smart charging method, the distribution of load demand throughout the day can be achieved.
3) While implementation of EVs guarantee decrease in $CO_2$ emissions, high penetration of EVs can result in challenges like voltage instability, overloads and increase in transmission losses.
4) Changing of EVs in off-peak hours helps in levelling the demand curve throughout the day.
5) Requirement of extra capacity is reduced by proper demand management. The cost of new transmission and generating resources are reduced.
6) Bidirectional EV interconnection allows Vehicle-to-Grid (V2G) power transfer [10].




Advantages for grid integration of PEVs

## IV. DIFFERENT CONTROL STRATEGIES OF SMART GRID[11]




Comparison of conventional and modern smart grid.

The conventional grid (micro grid) system had unidirectional flow of power unlike smart grid system and modern smart grid has additional communication networks. A comparative architecture is shown in Fig. 4. The difference in the structure of the smart grid system results in the requirement of different control strategies and new protection schemes.

Power fluctuations, voltage unbalance, frequency mismatch, transition management are the common challenges. Power fluctuation result due to variation in available resource and switching of resources. Increased loading result in voltage instability. Control strategy aim at handling scheduling, optimization of dispatch, system voltage and frequency and seamless transition between different modes of operation. Dynamic frequency control strategies are designed to incorporate the comfort level of EV owners while controlling the deviation of system frequency in a day. Smart charging strategies [9] help in minimizing this deviation. Participation factor and battery state of charge characterize each EV consumer. Switching of energy resources and fluctuations in availability results in variation of voltage level. The voltage regulation of the network is modified for large-scale incorporation of variable energy resources. Distribution management of flexible load systems allows economic and reliable handling of the distribution system.

It is necessary to monitor the operating states of the system at all times to improve observability, predict instability and facilitate data-based decision making for implementation of automation. Smart grid technologies allow flexibility so that the variable nature of renewable energy can be handled. A comparison of the different control strategies are presented in Table I.

TABLE 1 COMPARISON OF DIFFERENT CONTROL METHODS

| Control Method | Advantages | Limitations |
|---|---|---|
| Hierarchical Control Structure | Each level has a separate controller<br>Aims at voltage control, energy balance and minimisation of losses | The control mechanism needs to follow the physical restrictions on equipment e.g. grid cables. |
| Harmonic mitigation and droop control | Power sharing achieved by Control voltage & frequency / active power & reactive power based on operating mode<br>Harmonic mitigation is achieved | Droop control of inverters define operating state in islanded mode. |
| Hybrid control | Aims at optimum power distribution for continuous and discrete variations in load | Super-visionary control |
| Voltage and frequency control | Both centralised and distributed control | High-speed data processing is necessary |

## V. FUTURE CHALLENGES OF SMART GRID

Smart grid technology requires implementation of two-way communication for better connectivity. Security analysis, verification of protection logic, smart data-based decision making, intelligent channelling of power in transmission network, etc. are some of the challenges that need to be addressed for effective implementation of smart grid. Building of protection against cyber security threats is also an area of concern. Vulnerability and risk assessment, data security employing cryptography, improved privacy setting and log monitoring are being projected as solutions to security threats. Design of smart-charging plans for non-conventional loads like PEVs is necessary for effective load levelling. Ensuring standard power quality both in grid-connected and islanded micro-grid mode requires planning of rigorous control strategies for the modern grid.

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