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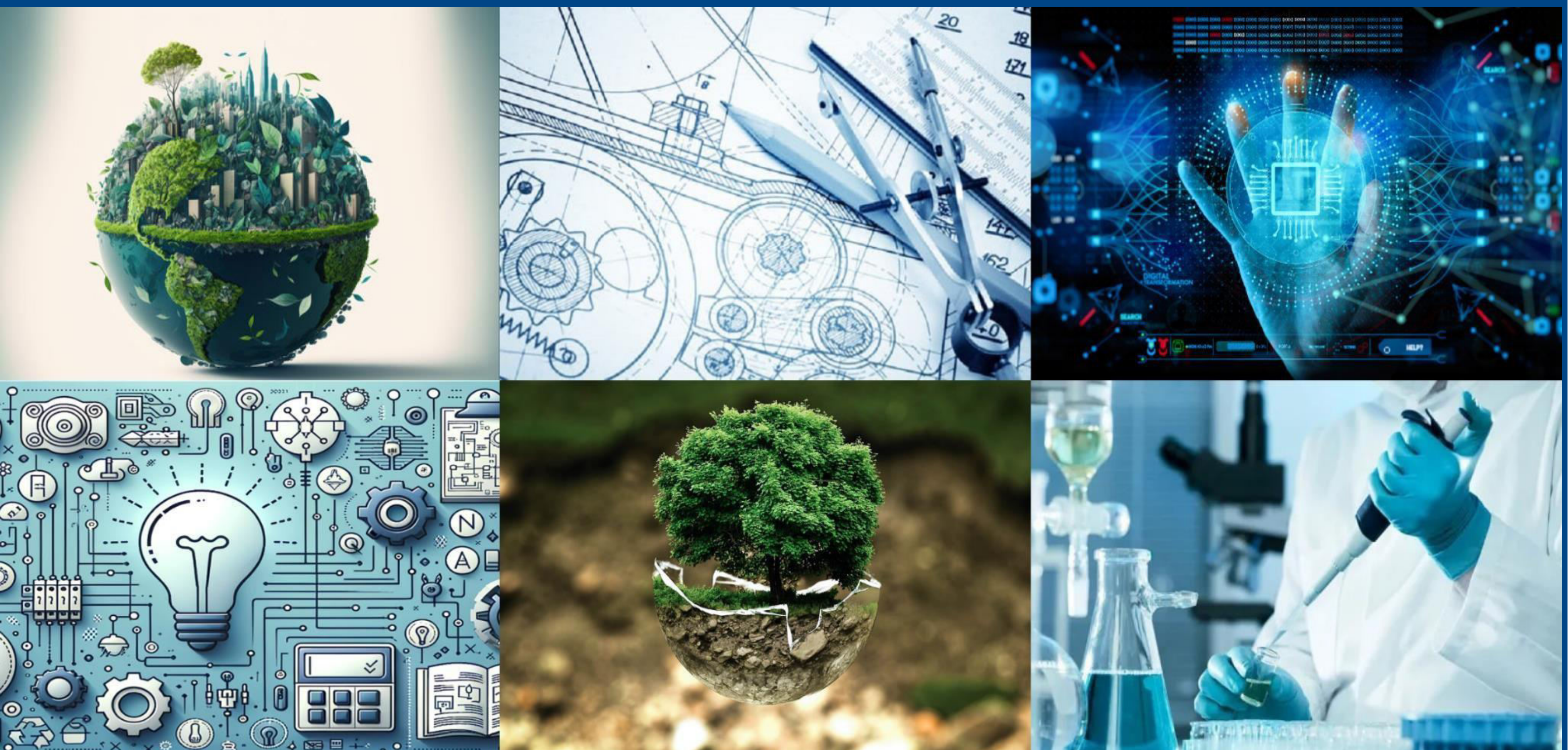

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Sizing of Voltage Source for a Battery Energy Storage System in Micro-Grid with Renewable Energy Sources

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ABSTRACT: The foremost challenge in a micro-grid with Distributed Energy Resources (DER) is of managing the intermittent nature of renewable energy sources. Therefore, the extent of integration of the Battery Energy Storage System (BESS) has increased recently in a micro-grid due to its versatility, high energy density, and efficiency. Generally, BESS is a grid-tied system and has fast power adjustment capability. Controversially, during the stand-alone mode, it cannot operate in the absence of a local Voltage Source (VS) which acts as a voltage and frequency reference in the network. To ensure the reliable operation of a micro-grid during utility grid outage or non-availability of intermittent renewable Energy Sources (RES), it is significant to operate the BESS with the local VS to dispatch the stored energy. This project discusses the analytical methodology that can be adopted for identifying the most suitable rating of the VS which can act as a voltage and frequency reference for the BESS using Matlab/ Simulink. Further, a simulation was carried out against various load characteristics and it is observed that an Uninterruptible Power Supply (UPS) with a kVA capacity of 35-45% of that of the BESS with an overload capacity of 150-200% can be chosen as a feasible choice to act as the VS.

KEYWORDS: MICRO-GRID - RENEWABLE ENERGY - SIZING OF VOLTAGE - ENERGY STORAGE – BATTERY

I. INTRODUCTION

1.1 GENERAL

Recently, the development of micro-grid has attracted the utilities greatly due to its network reinforcement and high-cost aging asset replacement [01-04]. Also, more renewable energy sources are getting incorporated into the power grid in the form of Distributed Generation (DG) or Distributed Energy Resources (DER) due to the increasing concerns about the environment and rising prices of energy dominated by coal and oil reserves which grasps a major stake at 66.73% as per the United Nations sustainable development goals (SDG) and Paris agreement commitments. This increasing penetration of DERs poses new issues and challenges to the power grid such as increased voltage transients, frequency variations, loss of reliability, and power quality reduction. Particularly, the planning and operation of the network are becoming a serious problem to ensure its reliability. Integration of large-scale Battery energy storage system (BESS) has solved these shortcomings because of its inherent advantages such as enhancement of extent of penetration of DER, increased grid flexibility, enhanced system reliability, emergence of new energy business models, and support to distribution system operators. Specifically, BESS coupled with power electronic converter systems offers rapid response for frequency regulation and load changes. It is considered as the most viable and promising approach which minimizes the active power oscillation and the settling time in smart grid power systems.

The recent advancements in Lithium-ion battery technology also offer various benefits in smart grids like high power, longer life, and high charge and discharge efficiency. In addition to a small size and low weight, Li-ion batteries can offer high energy density and storage efficiency, which makes them suitable for portable devices. It also deals with

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high fluctuating demands and is used to compensate for long-term and low-frequency power demands. It plays a crucial role to realize the flexible mechanism and optimal operation of active distribution networks. Hence, the placement and sizing of BESS directly influence the active management capability using DERs and the economic benefits of active distribution network operation. Further, a rule-based control method for a BESS is proposed by integrating with RES to dispatch energy on an hourly basis. On other hand, the use of BESS is still an expensive option and the control and supervision strategies are mandatory for their optimal performance according to the SOC (state of charge) values and deep discharge constraints. In order to maintain the distribution system economically, the sizing and placing of DGs with working constraints need to be carried out [05-08].

Comparing the benefits and shortcomings of the BESS in the grid-tied system, it is determined that the BESS cannot be operated in the absence of the main grid. Therefore, this work focuses on finding the judicious sizing of the Voltage source (VS) for the BESS based on the network characteristics. It can provide the reference parameters to the BESS during the outage of the grid and also provide the unbalanced currents to loads. In order to demonstrate the proposed system, a 100kVA Li-ion battery based Battery Energy Storage System (BESS) is considered which is specifically meant for brown field projects. It consists of three-phase four wire systems and consumes three balanced currents for charging and also provides three balanced currents while discharging. Therefore, it can be modelled as a three-phase current source [09-12].

II. PROPOSED SYSTEM

2.1 BLOCK DIAGRAM

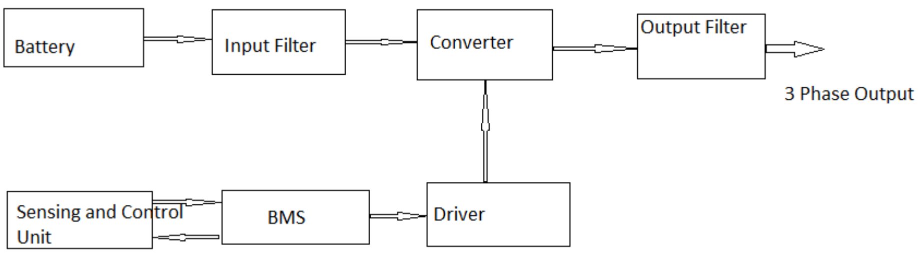

Fig 1; Block Diagram of proposed system

The proposed system consists of Battery which will be connected with grid. The input filter is used to remove even small quantity of ripple from various input DC sources and it will be given to the DC grid. From the DC grid the converter gets DC input and it converts to 3 phase AC. The Battery Management System (BMS) is used to manage the number batteries connected with the grid in various instant. Sensing and control unit is used to get feed-back signal from the converter and to control the converter by adjusting the firing angle.

III. SIMULATION DIAGRAM

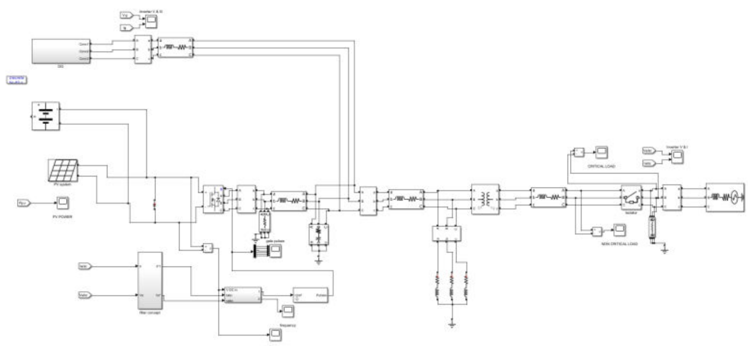

Fig 8; Simulation Diagram of Proposed System

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PV ARRAY SUB-SYSTEM

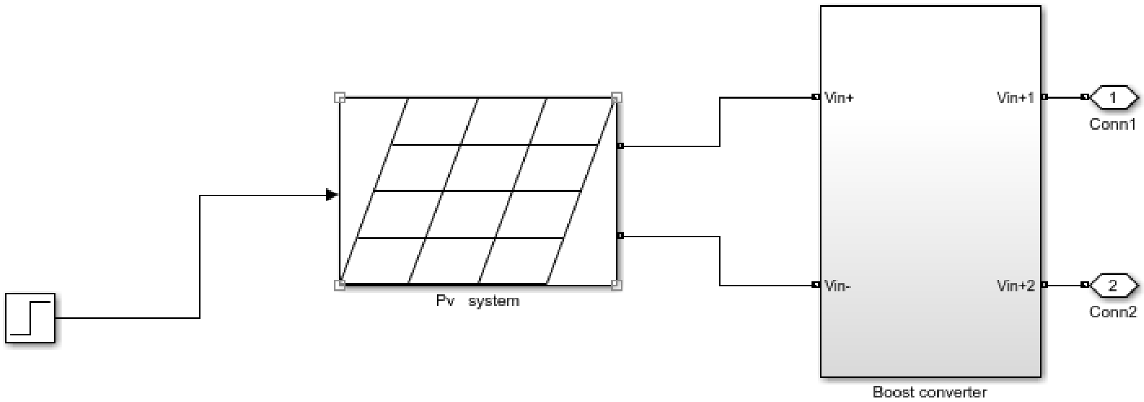

Fig 10; PV array system

A solar array is a collection of interconnected solar panels that work together to generate electricity. The panels are wired in series or parallel to increase voltage or current, respectively, and this system is connected to an inverter to convert the direct current (DC) power into usable alternating current (AC) power. The term "solar array" can refer to the physical panels on a rooftop, a large-scale solar farm, or a solar installation on other structures like a carport.

Diesel generator sub system

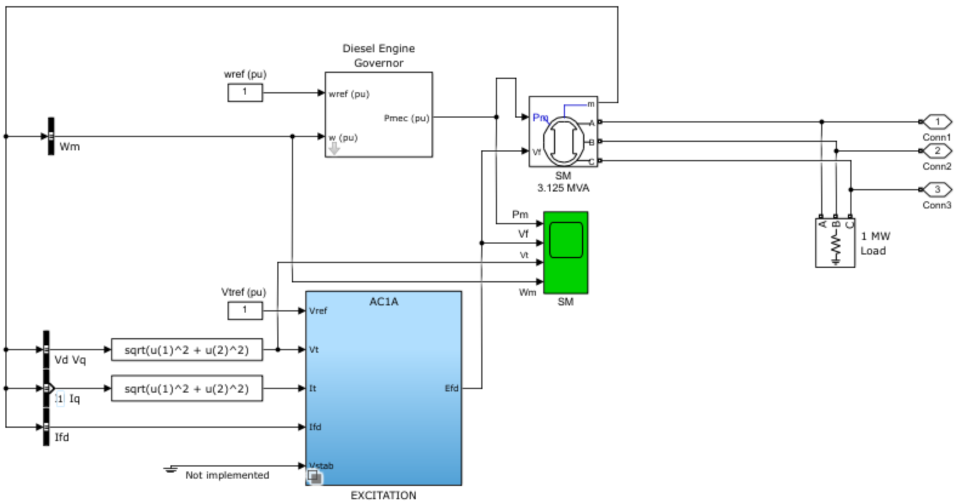

Fig 11; Diesel Generator System

A diesel generator subsystem in MATLAB can be built using Simulink to model the mechanical and electrical components. This includes subsystems for the engine, generator, governor, and excitation, often leveraging libraries like Simscape and power systems toolboxes. Researchers use these models to simulate dynamics, test control strategies, and analyze performance under various operating conditions, such as startup or load changes.

- **Diesel Engine:** Can be modeled using blocks from the Simscape Driveline library, which represents the engine's combustion process (suction, compression, power, exhaust) and transforms chemical energy into rotational mechanical energy.
- **Engine Governor:** A control system that regulates the engine's speed by adjusting the fuel supply to meet load demand.
- **Electrical Subsystem:** Represents the generator and its interaction with the grid.

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- **Generator:** A block representing the synchronous generator itself, which converts mechanical energy into electrical energy.
- **Excitation System:** Models the control of the generator's field winding to regulate terminal voltage.
- **Load:** Can be represented by an asynchronous motor or other loads to simulate the system's behavior under different power demands.

IV. RIPPLE FILTER

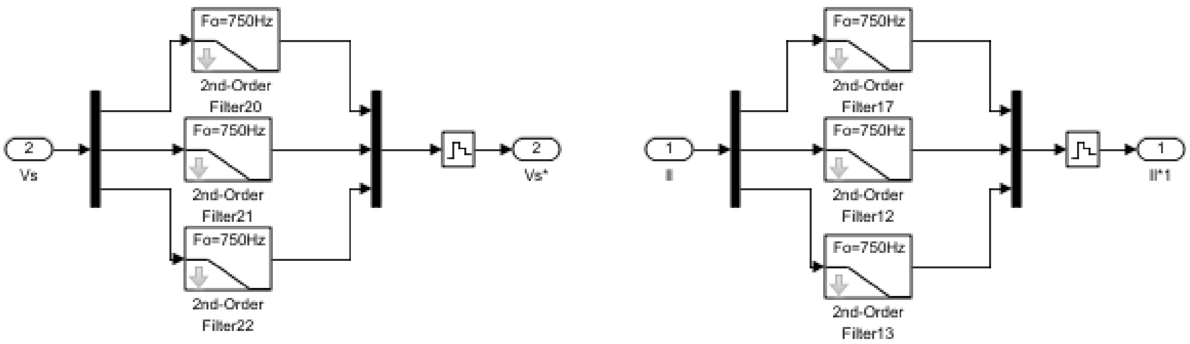

Fig 12; Filter Circuit

Voltage ripple is defined as the variation in DC voltage that occurs due to the fluctuations in the AC input voltage when produced by an AC/DC rectifier. It corresponds to the varying voltage around the DC level that is generated during rectification. The ripple filter, which consists of resistance (R_c) and capacitor (C_c) connected in series is used to filter out the noise from the PCC voltage caused by high switching of the interfacing inverter. This element is a high-pass first-order filter, which is tuned at half the switching frequency.

4.1 GATE PULSES

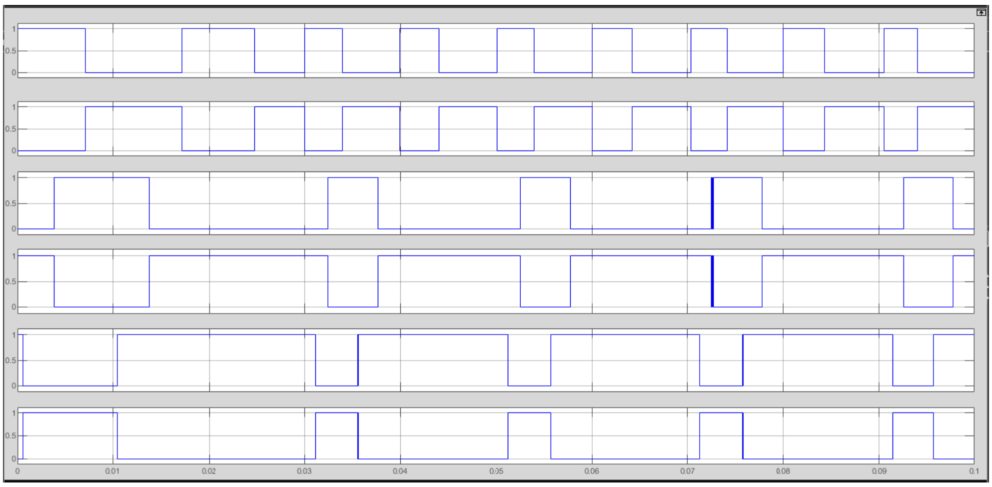

Fig 13; Gate Pulses

A gate pulse is a specific type of voltage signal applied to the gate of an Insulated Gate Bipolar Transistor (IGBT) to turn it on or off. To turn the IGBT on, a positive voltage greater than its threshold voltage (VGE) is applied between the gate and the emitter. This voltage pulse can be a simple pulse or, more commonly in modern applications, a complex Pulse Width Modulation (PWM) waveform that is generated by a control circuit.

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4.2 SIMULATION OUTPUT – ISOLATOR KEPT OPEN

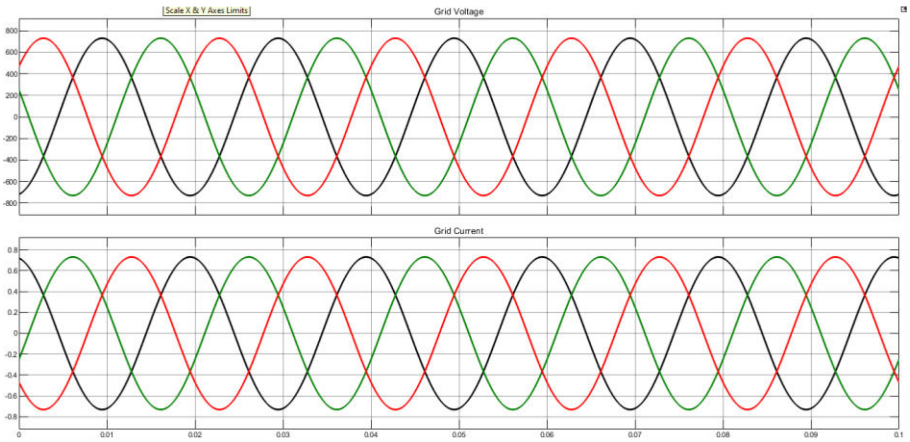

Fig 14; Output with Isolator kept open

4.3 SIMULATION OUTPUT – ISOLATOR KEPT CLOSED

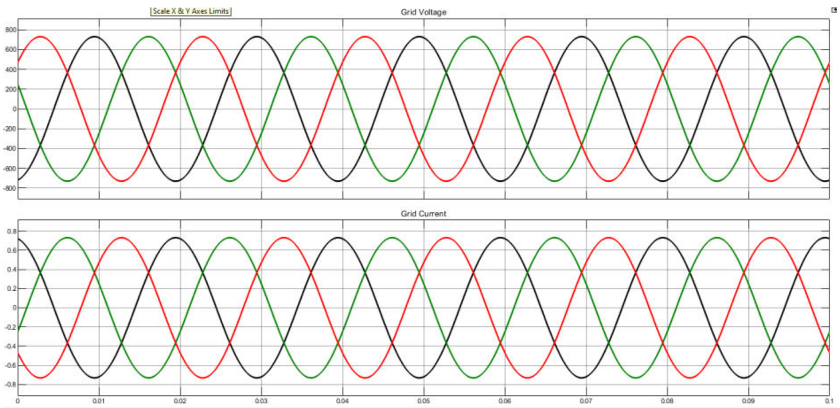

Fig 15; Output Isolator Kept Closed

4.4 SIMULATION NON CRITICAL LOAD OUTPUT – ISOLATOR KEPT CLOSED

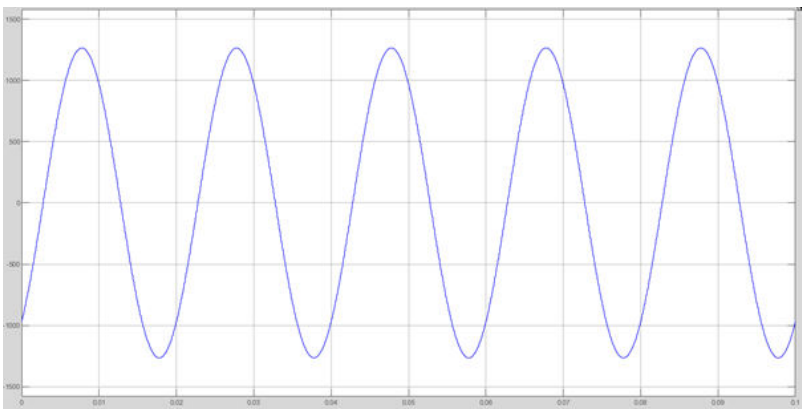

Fig 16; Non-critical load

V. CONCLUSION

The coordinated control of VS-BESS in a micro-grid under two scenarios—grid-connected and islanded mode—was proposed in this work. Using Matlab/Simulink and a selected network design, extensive simulation and analytical investigations were conducted. The suggested model has a thorough BESS and VS design that is controlled by a hysteretic current. Based on the findings and discussion in the preceding section, it can be concluded that VS-based BESS can provide the load with both actual and reactive power during a grid outage. The proposed scheme shows great effectiveness for sizing the VS to drive the BESS against diverse loading conditions. Additionally suggested are the processes for the BESS's reference current generation, the VS and BESS's active and reactive power sharing, and the computation of the % current imbalance. It was also observed that BESS ramping up is feasible with adequate time delay between events. The implications of power factors, nonlinear loads, and the proportion of load imbalance are examined, and the practical VS rating sizing for a successful hybrid micro-grid is calculated. Additionally suggested are the processes for the BESS's reference current generation, the VS and BESS's active and reactive power sharing, and the computation of the % current imbalance. It was also observed that BESS ramping up is feasible with adequate time delay between events. The implications of power factors, nonlinear loads, and the proportion of load imbalance are examined, and the practical VS rating sizing for a successful hybrid micro-grid is calculated.

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