Operational Risk Assessment and Validation of the Energy Storage System in Micro grids and Distributed Energy Applications

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Abstract - *in the present-day situation, in Indian market where energy requirement is huge, it is difficult to maintain a good quality and uninterrupted power which may cause damages and losses. To avoid this, concept of micro grids comes into picture. A micro grid has storage, generation and load systems connected to it. To help the environment, green energy is preferred in micro grids, which are not giving a fixed power output. This urges the need of storage system. As storage system is a key section of the micro grid it is important to have the system operating in safe condition. The main objective of the paper is to operate the system in safe condition, and to know the operational risks and hazards.*

Key Words: Battery energy storage system, distributed energy, hazard identification and risk assessment, micro grid.

1. INTRODUCTION

India being a country with about 1.3 billion population, there is a huge requirement of electrical energy to supply the residential, commercial and industrial loads. The utility electricity sector in India has one National Grid with an installed capacity of 344.00 GW as on 31 March 2018. Renewable power plants constituted 33.23% of total installed capacity. India is the world's third largest producer and third largest consumer of electricity. Electric energy consumption in agriculture was recorded highest (17.89%) in 2015-16 among all countries. The per capita electricity consumption is low compared to many countries despite cheaper electricity tariff in India. The conventional power system uses power generation in some regions where there is availability of resources required to generate electricity and then being transmitted to the different parts of the country through power grids. This conventional system has certain drawbacks like failure of one part of the grid can cause disturbance in a large part of the grid, the losses in transmission of power and the irregularities or disturbances in the power supply can cause damage to sensitive loads and can pose huge losses to industries. To avoid this problem distributed energy resources (DERs) are used. These DERs make use of generation plants of relevant capacity to supply for a given area, when there are disturbances in the grid or during outages of the grid. This concept of DERs gave rise to the development of micro grids (MG). These micro grids use energy storage for backup during outages or disturbances. Micro grids are the future of power distribution. When talking about any system it has certain risks and hazards associated with it, understanding them will help in safe operation of the system.

MGs require Energy Storage Systems (ESS) to give backup during outages. Among different ESS Battery Energy Storage System (BESS) have certain advantages over others. When an electrical drive is supplying a load, if the load changes suddenly, the excess or shortage of power is absorbed or supplied respectively by the battery as battery responds fast to the load changes, this is known as load following. Load following results in frequency regulation as changes in the load results in change of frequency of an electrical drive.

There is a need to charge the battery as it cannot discharge forever. The source to charge the battery is taken as solar PV system as it is the most suitable renewable source in India which has more than 315 solar days in a year.

2. METHODOLOGY

Table -1: Methodology followed

Battery System
• Mapping data/values from datasheet into the generic model of battery in MATLAB/Simulink • Validating simulation outcome with different types of loads
↓
Solar PV system
• Sizing of PV systems (series and parallel connections of modules) based upon the load requirement fulfilment along with Battery system • Development of MATLAB/Simulink model for solar PV array. • Implementation of DC/DC converter to stabilize the PV output.
↓
Integration of PV system and battery with DC load.
↓
Hazard Identification and Risk Assessment
• Understanding of the system schematics. • Estimating the possible hazards and risks associated with the system.

3. BATTERY SYSTEM

Among the different battery chemistry available, Lithium Ion Batteries are preferred here because of the higher efficiency, specific energy and energy density. Even if it costs more it is more suitable for the BESS usage. [1]

To understand the operational risks and hazards it is important to understand the system operation for which simulation is performed in MATLAB/Simulink platform. Initially battery alone is studied for different load combinations and we observe the transients of the system. The generic MATLAB/Simulink model is used and the parameters are altered to match a standard datasheet value. From simulation of the battery alone system it is observed that there is a need for charging of the battery as the temperature of the battery observes an overshoot when the state of charge drops to the maximum depth of discharge and the load is still discharge and the load is still connected to it, which is hazardous. Simulation setup is displayed in figure 1. The results are validated as per [2].

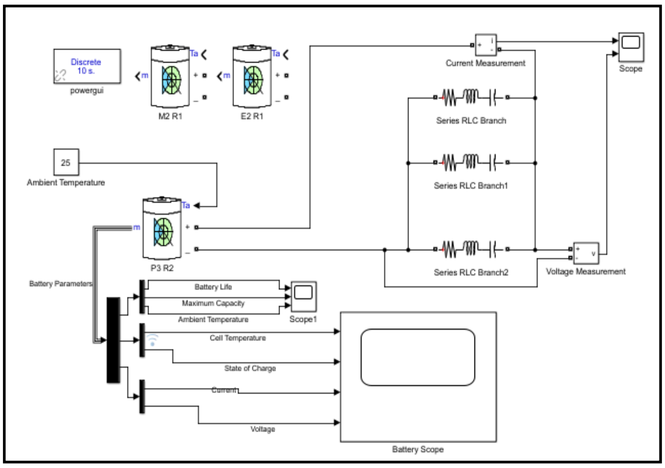


Fig -1: Simulation Setup for Lithium Ion Battery Study

4. SOLAR PV SYSTEM

As discussed in India solar PV system is preferred as there is an availability of more than 315 solar days. For simulating a

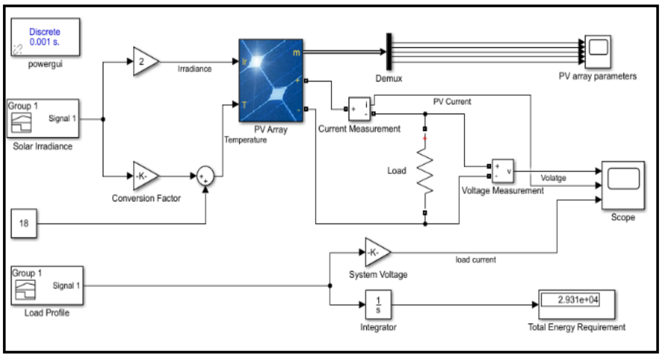
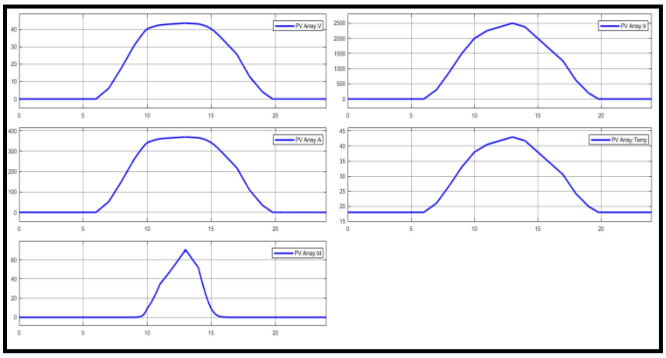


Fig -2: Simulation setup for studying Solar PV system

PV system, the generic model of a PV array is used and a Standard model is selected from the same. The sizing is done based on the load requirement and the energy required to charge the battery which should discharge to supply the load during off solar periods i.e. during night time when solar irradiation is not available or during any bad weather conditions. Simulation system is displayed in figure 2 and outcome in chart 1. A constant DC load which draws a

Chart -1: Simulation outcome of PV system



Current of 160A is used for simulation. Sizing is done based on [3]. From simulation it is observed that there is a need for DC/DC converter in order to maintain a constant system voltage at the required level for which a Buck converter is used which is a step-down converter i.e. it steps down the voltage level to the required value. Simulation setup with converter is displayed in figure 3 and the outcomes in chart 2. The converter design is done based on [4].

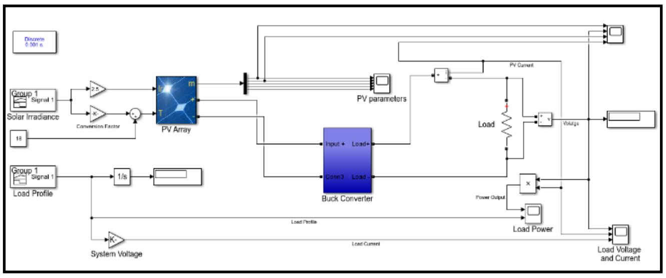


Fig -3: PV systems with Buck Converter

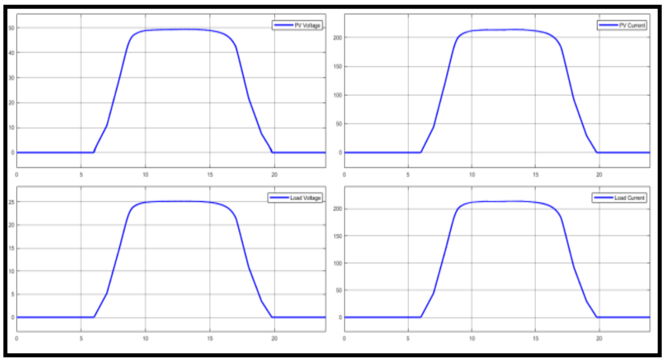


Chart -2: Simulation output of PV system with Converter

5. HYBRID SYSTEM

A hybrid system consisting of Lithium Ion battery and Solar PV system is used. The hybrid system is connected to a DC load which draws a constant current of 160A. During 12AM to 7 AM there is no solar irradiation or the irradiation is less which is insufficient to generate the power required to supply the load requirement. So, the battery discharges in

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this period (Assuming the battery is initially fully charged). As solar irradiation increases the solar PV output increases and the load is supplied from PV system. The excess of energy produced from Solar PV system is used to charge the battery. Once the time goes past 6PM the solar irradiation reduces and the PV system output is negligible, so the charged battery is discharged to supply the load. A battery charge controller is used which is required to limit the charging current of the battery in order to have a safe operation of the battery. The charge controller is configured using a saturation block and a controlled current source block in MATLAB/Simulink platform [5]. The simulation setup is displayed in figure 4 and the outcome in chart 3.

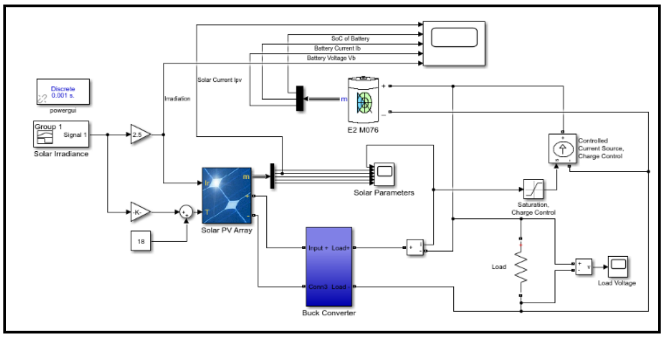

Fig -4: Hybrid System simulation setup

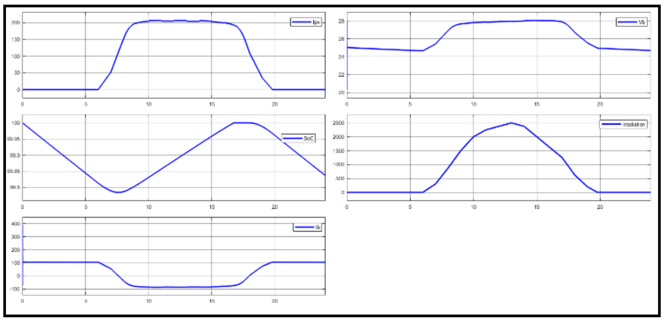

Chart -3: Hybrid system simulation outcome

In figure 4 it can be observed that when solar irradiation is available there is solar PV generation which charges the battery which can be observed from the state of charge curve. When the battery is charging, the battery current is observed to be negative as it is flowing into the battery.

6. HAZARD IDENTIFICATION AND RISK ASSESSMENT

Schematics of the system studied and the different blocks available are listed as follows

6.1 Battery Container

It is consisting of Battery bank and the battery container panel. It is the heart of a battery energy storage system.

Table -2: HIRA for Battery Container

Electrical	Thermal	Mechanical	System	Chemical
Short circuit	Fire	Crush/Dent	Contactor failure	Explosive gases
Overcharge	Elevated temperature	Drop	Loss of HV continuity	Electrochemical
Shock	Thermal Runaway	Shorting of electrodes	Manufacturing defects	Cell degradation

6.2 Control and AC DC Cabinet

It consists of all the control system used and the AC and DC systems with different sources.

Table -3: HIRA for Control and ACDC Cabinet

Electrical	Thermal	Mechanical	System	Chemical
Shock	Over heat, Heat dissipation	Stress and strain	Contactor failure	Toxic gases
High current and Voltage	Fire and Explosion	Loose Connections	Loss of HV continuity	Corrosion
Short Circuit of wire	Arc flash			

6.3 Power Conditioning System

Used for conditioning of the power and AC/DC conversion.

Table -4: HIRA for Power Conditioning System

Electrical	Thermal	Mechanical	System	Chemical
Supply failure	Explosions	Loose connection	Cyber attack	Flammable
High current and Voltage	Fire	Breakage	Workplace violence	Toxic gases
Short Circuit	High and low pressure			
Overload				

6.4 Solar PV System

Used as renewable energy source.

Table -5: HIRA for Solar PV System

Electrical	Thermal	Mechanical	System	Chemical
Short circuit	Over heating	Glass and cell breakage	Improperly installed	Corrosion
Over heating	Thermal Runaway	Loose Connection		
		Snail trails		

6.5 Coupling Transformer

It is used to connect to the main power grid.

Table -6: HIRA for transformer

Electrical	Thermal	System	Mechanical	Chemical
Insulation failure	Over heating	Bad workmanship	Improper joints or connection	Oil Leaks
Deterioration of the insulating oil	Fire	Poor quality of material	Ventilation failure	Hazardous gas
Prolonged over loading	Explosion	Less maintenance	Loose Connection	
Shock				

6.6 Auxiliary Distribution Board

The power supplies to the auxiliary devices are given from here.

Table -7: HIRA for Auxiliary DB

Electrical	Thermal	Mechanical	System	Chemical
Failure of breakers	Increased temperature	Uncalibrated Instruments	Failure of FDAS, HVAC	Hazardous gases
Shock		Loose Connection		
Overloading				

6.7 Switchgears

It is used for safety purposes.

Table -8: HIRA for Auxiliary DB

Electrical	Thermal	Mechanical	System	Chemical
Shock	Increased Temperature	Loose Connection	Lack of maintenance	Hazardous gases
Short Circuit	Fire hazards	Jammed contacts		Corrosion
		Mechanical Stress		

7. CONCLUSION

This paper helps in understanding the concepts of DERs, Micro grids, Energy Storage Systems, Lithium Ion batteries, Solar PV system and the risks and hazards associated with each of these. It is understood that every system has certain risks and hazards associated with them but in order to have a safe operation of the system the assessment of risk and identification of hazard is necessary. In order to complete the HIRA, the system behavior and the schematics had to be studied.

To study the system behavior the system was modelled and simulated in MATLAB/Simulink platform. The output of the simulations was validated and analyzed for possible operational risks and hazards. Starting with LIB, then solar PV followed by PV with Buck converter and finally the system which has LIB, solar PV and a Buck converter was used to supply a constant load. The system output showed that the battery is discharged when solar alone cannot supply the load and battery is charged when there is excess solar energy available

The study of schematics helped understand the different equipment present in a battery energy storage system and in estimating the risks and hazards associated with them. The BESS has different types of hazards and risks associated which can be categorized into electrical, thermal, mechanical, chemical and system hazards/risks. Every equipment has its own safe operating condition as mentioned in the datasheet failing to comply can cause a severe damage to the whole system based upon its criticality. Maintaining of the operating conditions is a key objective to mitigate most of the discussed hazards and risks.

The HIRA discussed in this report can be used to operate the system safely by using proper precautions. This paper will also be useful for hazard mitigation of battery energy storage system.

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