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Grid-Integrated Industrial Motors-Driven Solar Water Pump with Power Flow Management

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Abstract: A low-level distributed nonlinear controller for a DC MicroGrid integrated in a Smart Railway Station capable to recover trains' braking energy is introduced in this paper. The DC MicroGrid is composed by a number of elements: two different types of renewable energy sources (regenerative braking energy recovery from the trains and photovoltaic panels), two kinds of storages acting at different time scales (a battery and a super capacitor), a DC load representing an aggregation of all loads in the MicroGrid, and the connection with the main AC grid. A hybrid DC microgrid with a stochastic power resource such as a PV, Photovoltaic, battery, and a super capacitor is studied in this project to stabilize the voltage. The PV is considered as the main power resource while battery and super capacitor are considered as supplementary power sources for long-term and short-term power insufficiency. Fuzzy logic, namely ANFIS, controller is proposed to control bus voltage, and decreasing the stress upon the battery of , and transfer energy between ancillary sources in an appropriate timely manner. The proposed methodology is compared with the conventional controller approach, and the effectiveness of the proposed method is investigated by a simulation for different types of energy inequality conditions.

Key words: DC-DC converter, battery storage, ANFIS, PV System, DC Micro Grids, Grid stability, AC Microgrid.

I. INTRODUCTION

Today PV systems are becoming more and more popular, with the increase of energy demand and the concern of environmental pollution around the world. Four different system configurations are widely developed in grid-connected photovoltaic power applications: the centralized inverter system, the string inverter system. In order to mitigate the energy crisis and environmental pollution issues, the distributed power generation systems which exploit renewable energy sources, such as solar and wind energy, have gained a great interest. In solar power systems, the photovoltaic (PV) grid-connected inverter converts the dc power generated from the PV panel into the power grid. The two-stage PV grid-connected inverter, consisting of a front-end dc-dc converter and a downstream dc-ac inverter, has been widely applied since the output voltage of the PV panel has a wide variation range .The front-end dc-dc converter functions to realize maximum power point tracking (MPPT) of the PV panel, and the downstream dc-ac inverter is responsible for regulating the intermediate dc bus voltage and injecting high-quality ac current into the power grid.

Distributed generators are integrated with storage facilities and loads to form an autonomous DC microgrid. To overcome the control challenges associated with coordination of multiple batteries within one stand-alone microgrid, control layer is established by an adaptive voltage droop method aimed to regulate a common bus voltage and to sustain the States of Charge (SOCs) of batteries close to each other during moderate replenishment [5]. In [6] incremental conductance algorithm is used to track maximum power from photovoltaic power plant in a DC microgrid. Mathematical models of fuel cells, photovoltaic, and ultra capacitor converters for the control of power plant are described in [10]. In [12], a parametric programming-based approach for the energy management in microgrids is proposed. A parametric mixed-integer linear programming problem is, in addition, formulated for a grid-connected microgrid with photovoltaic, load demand, and energy storage facilities.

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DC-DC boost converter

Power for the boost converter can come from any suitable DC sources, such as battery, PV, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC converter.

A boost converter is a DC to DC converter with an output voltage greater than the input voltage. A boost converter called a step-up converter and its "steps up" the source voltage. Since power ( ) must be conserved, the output current is lower than the input current. Examples of DC to DC converter are:

- **Boost converter** is power converter which input voltage is less than DC output voltage. That means solar input voltage is less than the battery voltage in system.

II. PV CELL MODELING

A p-n junction fabricated in a layer of a semiconductor forms a photovoltaic cell structure. The ideal solar cell is a semiconductor diode connected in parallel to a current source with series resistance, and parallel resistance as shown in Fig. 2 [13].

Fig. 1. Photovoltaic unit

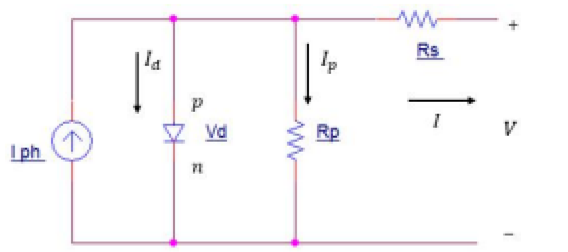

Fig. 2. Equivalent circuit of a PV cell with single-diode model

$$I = I_{ph} - I_0[e^{\frac{q(V+R_sI)}{nkT}} - 1] - \frac{V + R_S I}{R_{ph}} \quad (1)$$

$$V_d = V + IR_s \quad (2)$$

A simple equivalent photovoltaic cell circuit model includes a diode in parallel with a current source and a resistor as shown in Fig. 2.

III. PROPOSED SYSTEM

In this project, a DC MicroGrid for a Smart Railway Station equipped with renewables, as PVs and regenerative system, storage devices, and loads is proposed, which is able to connect or disconnect to the AC main grid, and the low-level control laws needed to let the MicroGrid correctly operate are introduced, together with a complete stability analysis.

The targets are to merge regenerate energy from the trains (that can be very significant) to the one produced by PV and to keep a desired voltage level for the DC bus. The combination of the two renewable sources stresses the system with respect to any kind of perturbation can take place. The stability of the DC MicroGrid is ensured by different time scale storage devices utilization (batteries and supercapacitors), in order to obtain a flexible and reliable system in response to the intermittent nature of the renewables:

CIRCUIT DIAGRAM

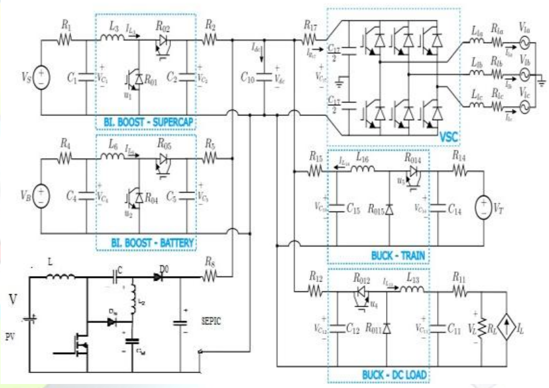

Fig: Proposed circuit diagram

ADVANATGES

- Good Voltage stability
- High Voltage gain
- Fast time response
- Life time of time increase

IV. CONTROL STRUCTURE

Conventional PI controller

To control the voltage of the main bus of DC MG, charge, discharge of the battery, charge, discharge of the super capacitor, and define the duty cycle of the OVD phase, two cascade PI controllers have been considered for each of phases. In outer control loop, bus voltage error is given to the PI controller and output of the PI controller provides current reference for the battery, the super capacitor, and the OVD phases. Another

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PI controller is used separately to track the current reference by providing the duty cycle of the converter of battery, super capacitor, and OVD phases.

Fuzzy inference system (ANFIS)

A Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. It was introduced by Lotfi Zadeh in 1973. A fuzzy inference system includes fuzzification, membership function, if-then rules, fuzzy logic operators, and defuzzification. There exist two type of fuzzy inference systems, namely a Mamdani's fuzzy inference method and a Sugeno-type fuzzy inference system. The Mamdani's method is among the first control systems, built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and a boiler combination by synthesizing the set of linguistic control rules obtained from some experienced human operators. In this paper, an expert knowledge has been used to build the initial fuzzy and then, the PSO has been applied to optimized fuzzy membership functions.

- Adaptive Neuro-Fuzzy Inference System (ANFIS) is a neural network functionality equivalent to fuzzy inference system.
- This architecture has the potentials to capture the benefits of both the neural network and the fuzzy logic in one.
- It is based on the "First Order Sugeno Model",

Supercapacitor Subsystem

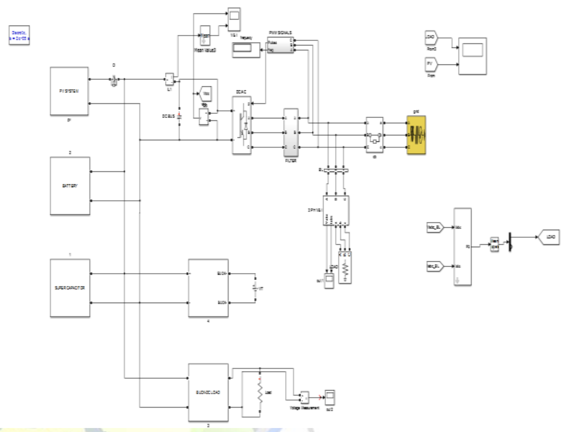
The supercapacitor is an energy storage device, which is used to improve power quality, due to its capability to provide a fast response to grid oscillations. It has a high power density and an increased life cycle while having a considerably low energy density. The combination of such device with a slower one allows to ensure proper control and management strategies of the power flow, dealing with the multiple-timescale characteristic of DC MicroGrids. Indeed, combining the battery characteristics with the supercapacitor ones, it is possible to have the supercapacitor acting to counteract to grid transient variations, while the battery deals with the power flow.

Battery Subsystem

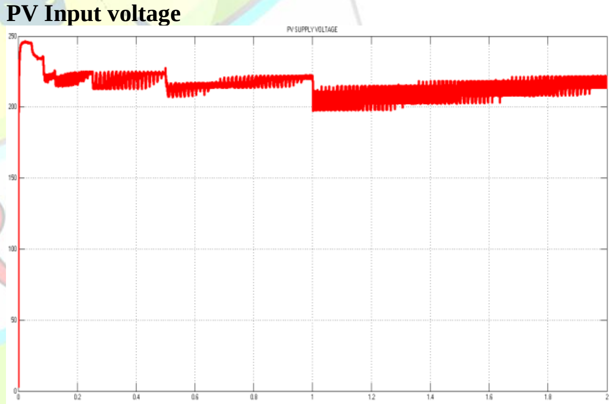
The battery is a storage device which is usually used as energy reservoir. Here, an ion-lithium battery bank is considered. Compared to other battery technologies, this kind of battery has a higher energy density, longer life cycle, and absence of memory effect. The target of the battery is to regulate the power flow in the system according to a reference given by the secondary control level. A proper sizing is mandatory for the battery to be able to inject or absorb the needed amount of power. A piecewise constant power supply is demanded for maximizing the lifetime

V. SIMULATION RESULTS

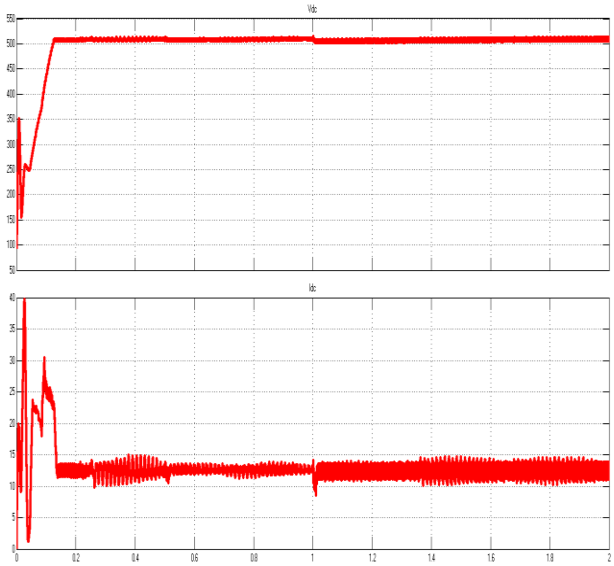
Simulation circuit diagram



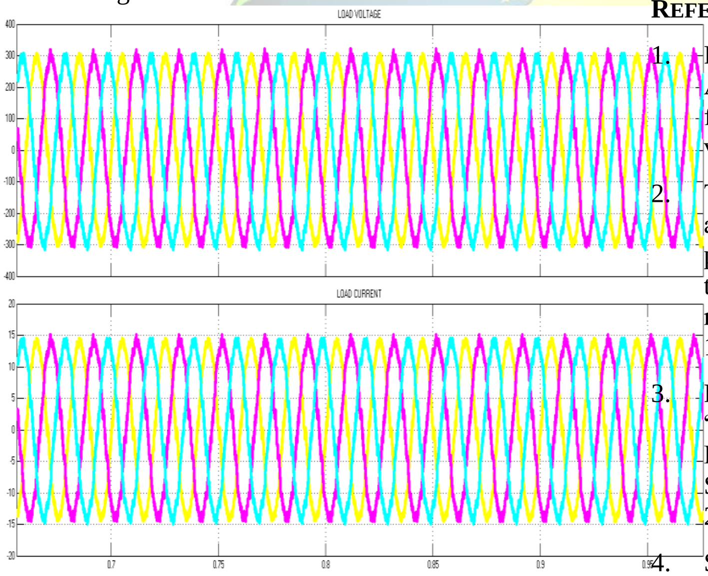
PV Input voltage



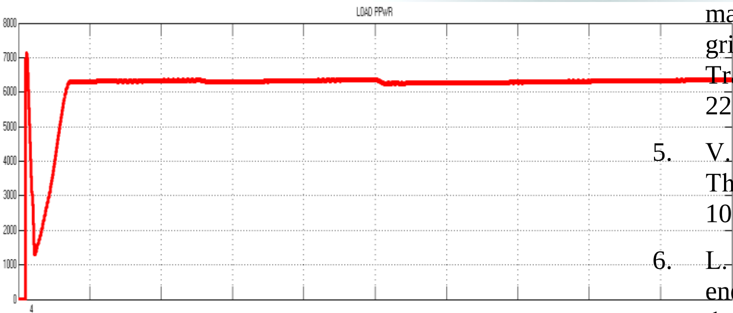
DC BUS Voltage and Current



Load voltage and Current



Load Power



VI. Conclusion

This project addresses the problem of controlling a grid-connected DC MicroGrid for a Smart Railway Station. The proposed MicroGrid is used to absorb the train braking regenerative power, which constitutes a very large and sudden peak of power that is difficult to address by classical linear controllers. This MicroGrid is also used to integrate distributed generation as PV arrays. The proposed system is based on two energy storages with different time scales, i.e., a battery and a supercapacitor. This proposed system represents a new control methodology for DC Microgrid control. The inputs of proposed fuzzy controller get four variables that is the error of bus voltage, the integrated error of bus voltage, the SOC of the battery, and the SOC of the ultracapacitor to define currents of stabilizer units. The simulation has shown the proposed controller is successful in bus voltage regulation. The main contribution of the proposed method in comparison to the others is lower stress on the battery and also proper energy transmission between different storages when one of them is almost full charged

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