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DC MICRO GRID FOR A SMART RAILWAY STATION INTEGRATING RENEWABLE SOURCES

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Abstract : The nonlinear low-level distributed controller for a DC Micro Grid integrated with Smart Railway Station which is capable to recover trains' braking energy. The DC Micro Grid 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 Micro-Grid, and the connection with the main AC grid. A hybrid DC micro-grid 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 controller is compared to the conventional controller, and the effectiveness of the proposed method is determined by a simulation for various types of energy inequality conditions.

Index Terms - DC-DC converter, battery storage, ANFIS, PV System, DC Micro Grids, Grid stability, AC Micro-grid.

1.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 various system configurations are developed in the grid-connected photovoltaic applications. 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 to storage facilities and loads to form an autonomous DC micro grid. To overcome the control challenges associated with coordination of multiple batteries within one stand-alone micro grid, control layer is established by an adaptive voltage droop method. [5]. In [6] incremental conductance algorithm is used to track maximum power from photovoltaic power plant in a DC micro grid. 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 micro grids is proposed. A parametric mixed-integer linear programming problem is, in addition, formulated for a grid-connected micro grid with photovoltaic, load demand, and energy storage facilities.

2.1DC-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.

2.2PV Cell Modelling

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. 2.2 [13].

Fig. 2.1. Photovoltaic unit

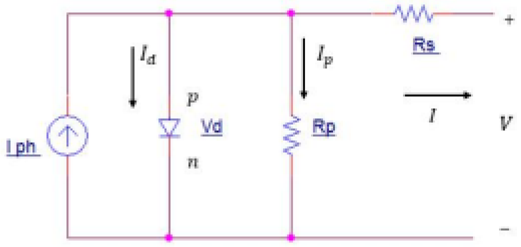


Fig. 2.2 Equivalent circuit of a PV cell with single-diode model

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

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

A simple equivalent photovoltaic cell circuit model includes a diode in parallel with a current source and a resistor as shown in Fig. 2.2

PROPOSED SYSTEM

A DC Micro Grid 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 Micro Grid 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 Micro Grid is ensured by different time scale storage devices utilization (batteries and super capacitors), in order to obtain a flexible and reliable system in response to the intermittent nature of the renewables.

3.1 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 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.

3.2Fuzzy 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",

3.3Supercapacitor Subsystem

The super capacitor 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 Micro Grids. Indeed, combining the battery characteristics with the super capacitor ones, it is possible to have the super capacitor acting to counteract to grid transient variations, while the battery deals with the power flow.

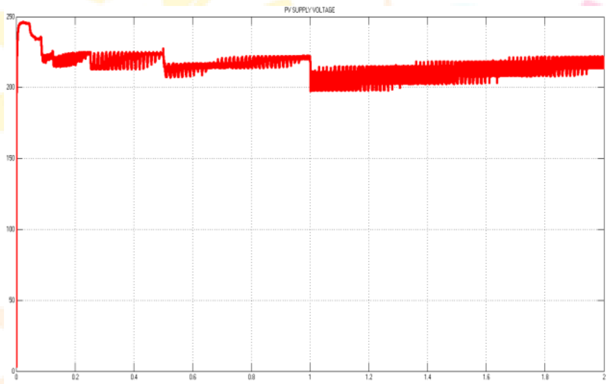
3.3 Battery Subsystem

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

IV. RESULTS AND DISCUSSION

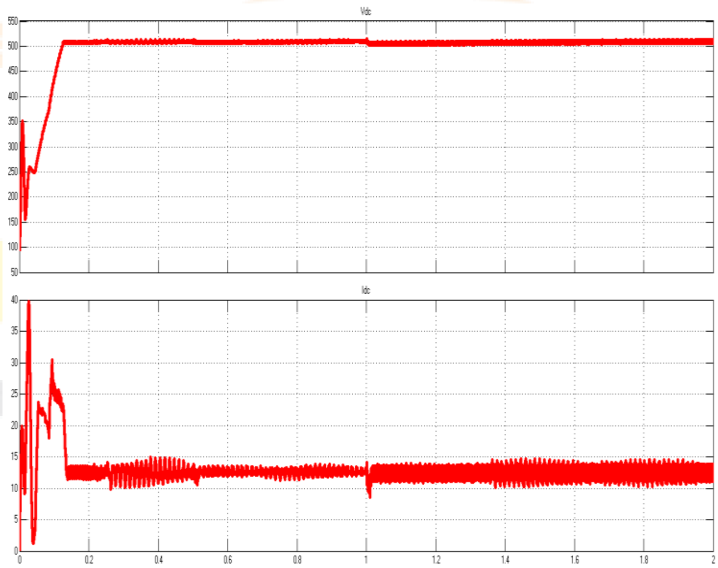
4.1 PV Input voltage

PV input voltage is varying from 30V to 40 V



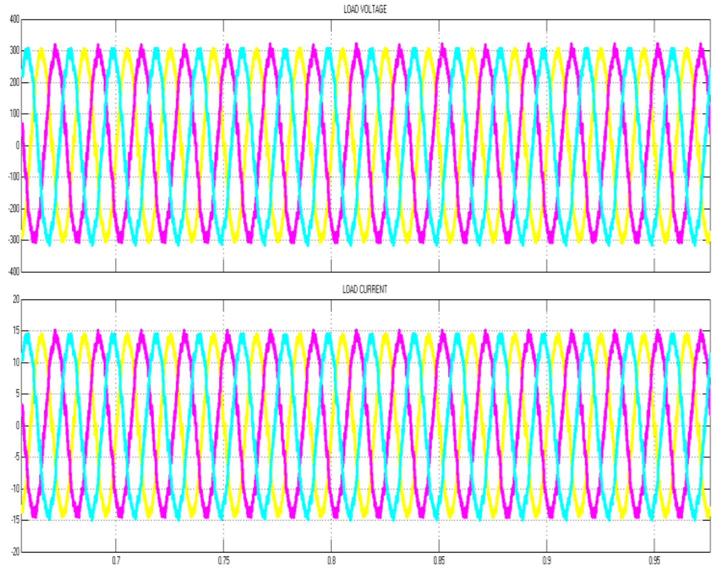
4.2 DC BUS Voltage and Current

DC bus voltage=500V and current=15A



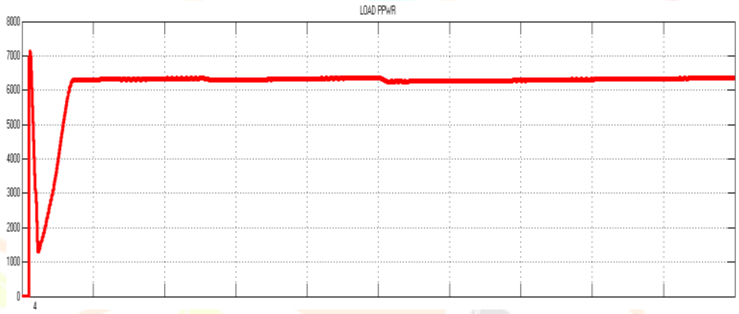
4.3Load voltage and Current

The Load voltage=30V and load current=15A



4.4Load Power

Load Power=620W



Conclusion

The problem of controlling a grid-connected DC Micro Grid for a Smart Railway Station. The proposed Micro Grid 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 Micro Grid 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 super capacitor. This proposed system represents a new control methodology for DC Micro grid 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 ultra capacitor 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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