Design of Charging and Discharging of Battery in a Renewable Energy based DC Micro-grid

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Abstract: Now a day increasing demand for energy is creating problems for the power distributors, like grid instability due to overload so that this reason yields in development of power distribution systems using renewable energy without uninterrupted power supply. Several types of Distributed Generations, local loads, storage system and voltage source converter can be connected together to form a minor local power generation system called as micro-grid. In order to achieve the system operation under islanding conditions battery power limitation is proposed, this model uses control of power electronics interfaced with Distributed Generation systems in micro grid. In this topology, battery connected parallel to DC link of the voltage source converter with charging and discharging scheme across the dc motor. The proposed topology is verified in MATLAB/Simulink environment.

Key Word: Distributed generation; load shedding; Micro grid; Renewable energy sources, Grid connected mode, MATLAB/SIMULINK.

1 .INTRODUCTION:

Power system deregulation, discontinuous power supply has led to distributed generation with renewable sources with clean environment [1]. DC micro-grids like AC ones can operate in grid-connected or islanding mode. Considering the cost of the battery, assuming a suitable charge/discharge control strategy for the well-organized use of the battery in order to achieve high state-of-charge (SoC %) and decaying its life is a serious issue. In the charging mode, a battery charger is necessary to ensure a full charging of the battery and prevent overcharging, to increase the lifetime of battery [2][3]. Production of more energy combinations with suitable development approaches using Renewable Energy with Uninterrupted power supply when Micro-grid fails with minimum loss[4][5]. Micro-grid comprising of hydro turbines (micro sources) with a new controller topology which controls (i) voltage and frequency of each micro source (ii) synchronization of micro sources after a fault in one micro source (iii) avoid load shedding condition during fault in any one micro source.

The rest of this paper is organized as follows. Section II describes the System Configuration. Section III explains the Battery Modelling and mode of operation, Charging Method. Section IV shows Simulink model and the result. Finally, Section V shows the conclusion.

2. SYSTEM CONFIGURATION:

Micro-grid architecture is shown in fig (2.1). The micro-grid is operating in islanded mode. Islanding is a situation where micro grid is disconnected from the main source but remains energized and continues to supply local loads with the coordination of rechargeable battery. The selection of the battery converter size was based on its capability to supply the required three-phase short circuit current at load. Thus, the rated current of the converter should be 100A, which leads to 1000kVA at rated voltage 440 V. In this paper however, it was assumed constant (20mΩ) because the control method applied in the battery converters are not much sensitive for the variations of the battery terminal voltage. An LC filter (L=100mH, C=600μF) is used in signal processing unit.

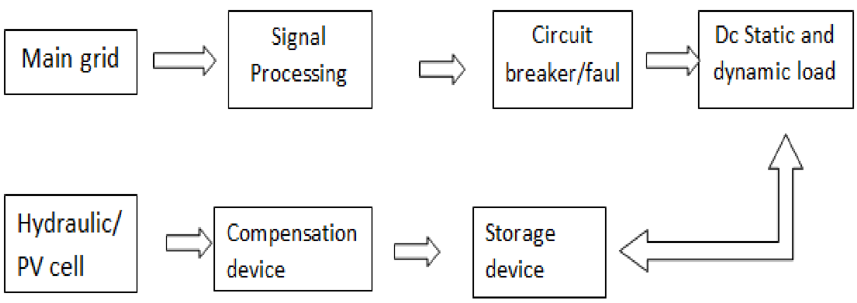

Fig 2.1 shows Micro-grid architecture with Renewable Energy Sources

3. BATTERY MODELLING:

A proper charge–voltage model is necessary in order to study the battery behaviour during charge and discharge conditions. Due to the non-linear characteristic of battery, it's appropriate the controlling is a challenge. In renewable based micro-grid with a power generation system, it is important consideration to study the dynamical behaviour of batteries. Different models for simulating battery behaviour with different of complexity and precision are available. These models can be categorized into three types; electro-chemical, mathematical and electrical models. In Electro-chemical models, it characterizes the battery mechanisms by different types of differential equations. These types of models are too complex for controlling purposes and are useful for calculating actual conditions of the battery. In mathematical models, the performance of the battery is described by some empirical equations. Electrical models represent the battery behaviour with the help of basic electrical elements, such as voltage and current sources, resistors and impedances. Various types of such electrical models have been recommended in the works. The simplest electrical model of a battery consists of an ideal voltage source in series with a constant internal resistance. In the Thevenin equivalent model, transient and steady behaviour of the battery can be simulated.

However, Thevenin model only considers about battery discharging and charging, and steady state behaviour of the battery cannot be simulated. Models that are more realistic have been proposed to take into account of non-linear parameters and the battery dynamical behaviour. A dynamic battery model for Ni-MH batteries is proposed in this paper. This electrical model characterizes different working zones for battery run-time, that is, saturation, overcharge, charge, discharge and over-discharge zones shown in Fig 2. Results show that this model can satisfactorily prove the behaviour of batteries during the Charge/Discharge processes; however, the transient performance of battery cannot be investigated through such models. According to the above explanation for the battery modelling and in order to apply a proper model for both charging and discharging processes, a combinatory model based on the run-time based and Thevenin model is modified and used in this paper in order to simulate charge/discharge behaviour of the battery in the proposed control strategy. In this model, the voltage source represents the battery open circuit voltage models the internal resistance of the battery, which contains the effect of operating point.

A. Mathematical flow chart of a Battery Model

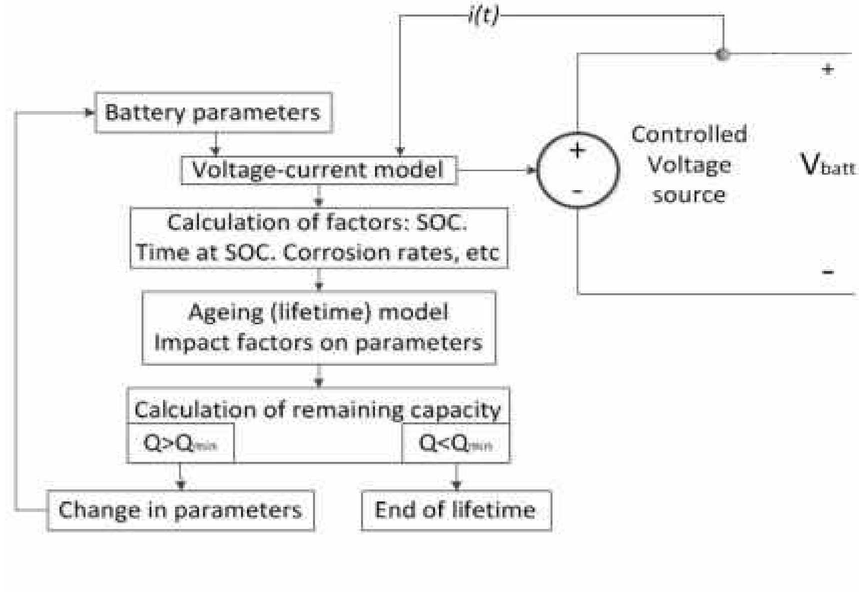

Fig. 3.1Flow Chart of a Battery Model

The battery capacity "Q" does not change with the current amplitude; the temperature does not affect the model's behaviour; the aging of the battery is not considered; the self-discharge is not included. Those factors can be considered in a more complete mathematical battery model as shown by figure 3.1, in which battery parameters change during the lifespan of the battery to provide an ageing profile and degradation of battery performance affected by many other factors.

B. Mode of Operation

(i) Islanding mode

Control of micro source is critical in islanded mode as each micro source has limited capability. If the load connected is much greater than generated power of the micro grid, load shedding of non-critical loads is obvious. The performance controller for micro grid under balanced/unbalanced non-linear

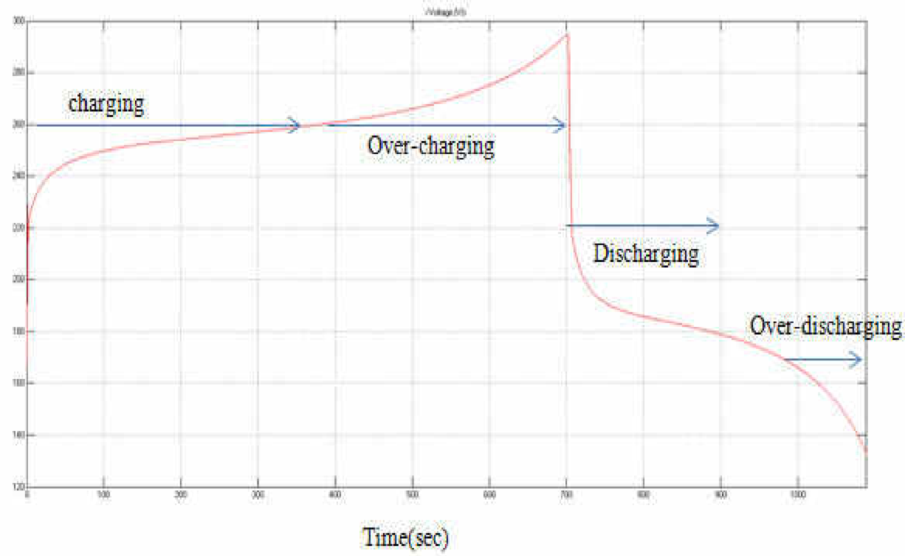

Fig.3.2 Charging and Discharging curve of Ni-MH Battery

load is shown in Figure 3.2. Before the application of consumer load, the battery is charged by the generated active power of each SEIG. Load shedding is done across non-critical loads are applied at 100s. At 100 sec, power is disconnected, hence load becomes unbalanced. To maintain the uninterrupted supply battery comes in act and start to discharge, and charging of battery. Hence the effectiveness of the reduced rating constant current controller can be observed under unbalanced conditions.

(ii) Failure of one micro source in islanding mode:

After 100sec, micro source load is cut off from rest of the system due to fault. Since the load connected to this micro source is critical, it has to be shared by the remaining two plants. This results in discharging of batteries. After the fault clearing micro source has to be reconnected to the system. Under such condition phase of the three sources should be matched for reconnection shows the overlapping of a connected and the disconnected micro source.

It can be observed that the disconnected micro source is effectively resynchronized with load. After that it can be observed that the proposed reduced rating controller, in addition to voltage regulation effectively resynchronizes the micro source connection. Fig 3 shows the disconnected micro source (Vdc), the remaining micro sources (Vdc).

C. Charging Method:

Batteries are charged by the method called Constant Current Constant Voltage (CCCV). A charging method, sources constant current is used in the battery in an attempt to charge the battery voltage up to a pre-set value. Once this voltage is reached, the charger will source only enough current to hold the voltage of the battery at this fixed voltage. The reference voltage is commonly the batteries full voltage ± 50mV, and 1C as the full charging current that can be used for battery. The accuracy on the set point voltage is much critical, if this voltage is high, the number of charge cycles the battery can complete is reduced. If the voltage is much low, the cell is not fully charged. The constant current limit is state of charging in which the maximum charging current is flowing to the battery, due to the battery voltage is the set. The charger senses this state and sources maximum current to force the battery voltage up.

4. SIMULATION MODEL AND RESULT:

A. Simulation Model:

Figure 4.1 shows the model of Battery connected parallel to DC link voltage.

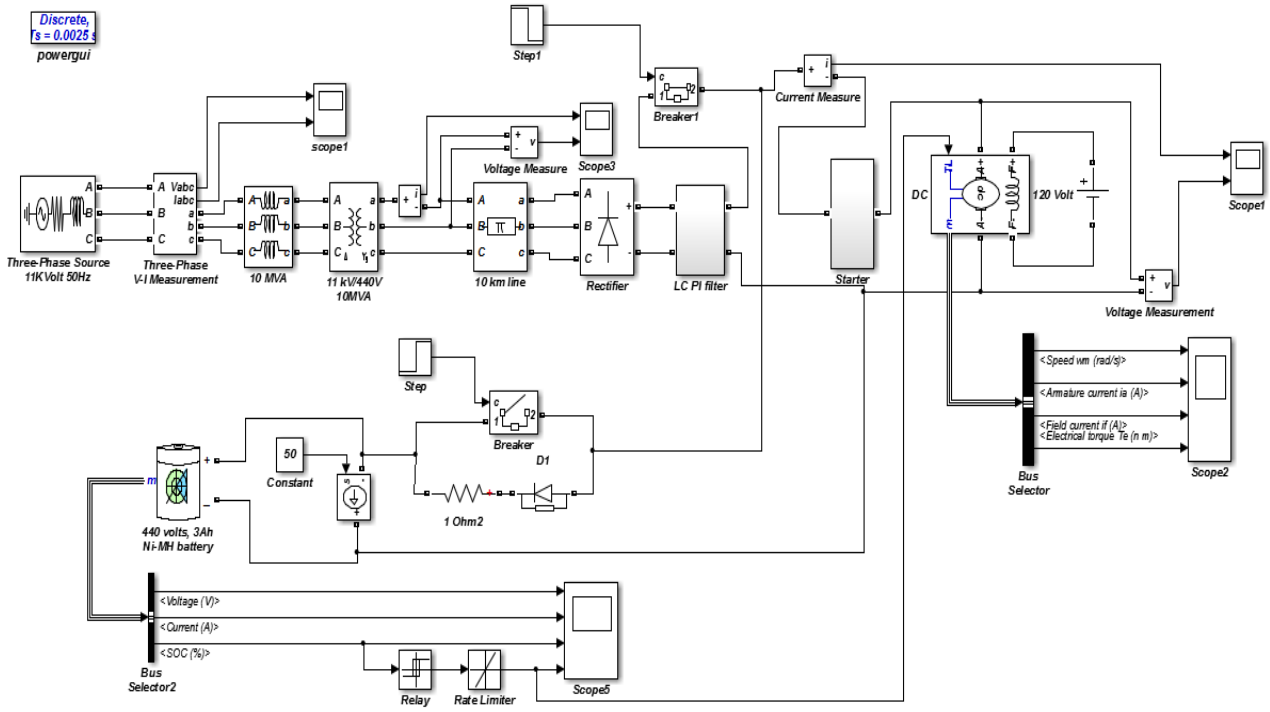

Fig. 4.1 Design of Charging and Discharge of Battery in a Battery based DC Micro-grid

B. Simulink Result:

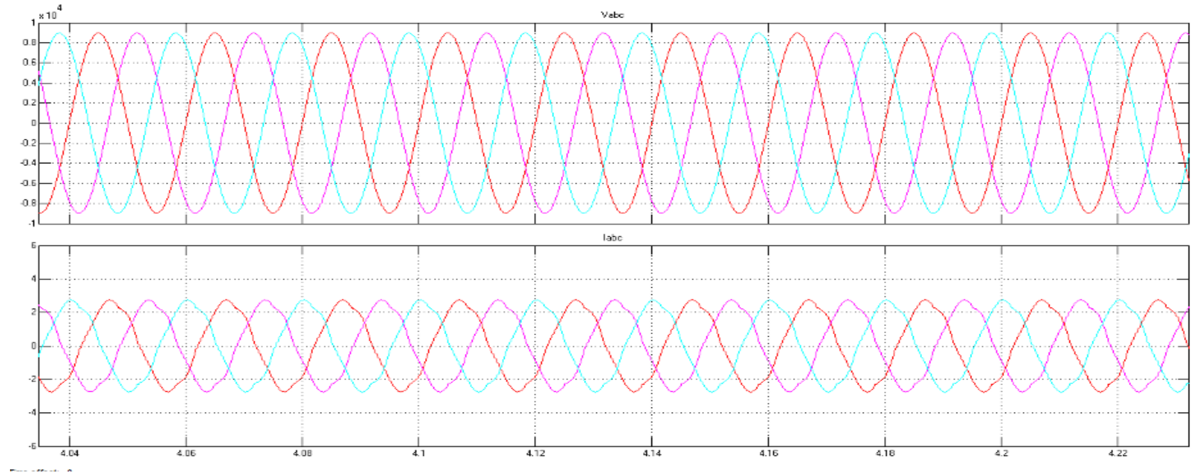

Fig 4.2 Three Phase Power Supply by AC Transmission Line

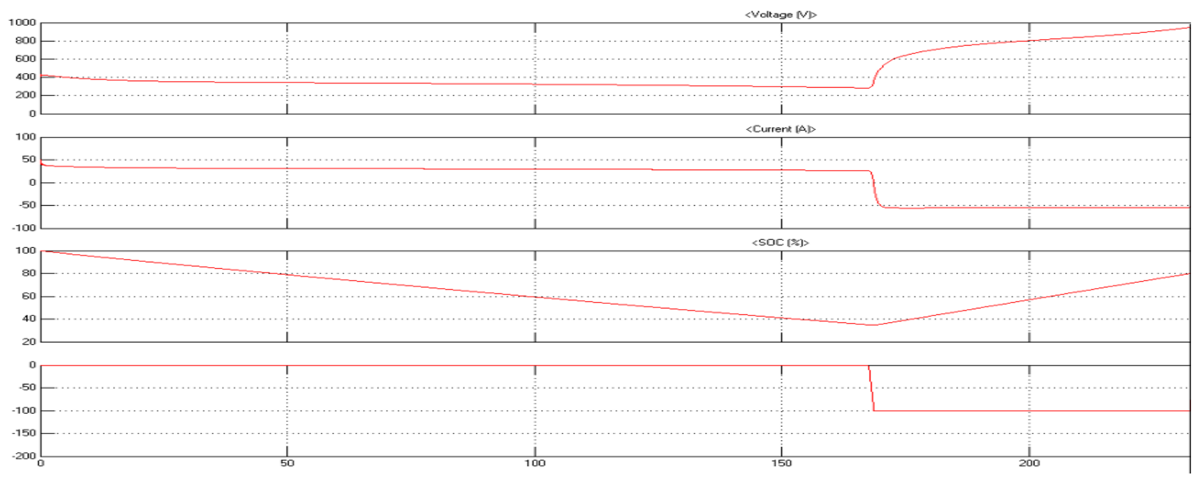

Fig.4.3 Rechargeable Battery Parameter

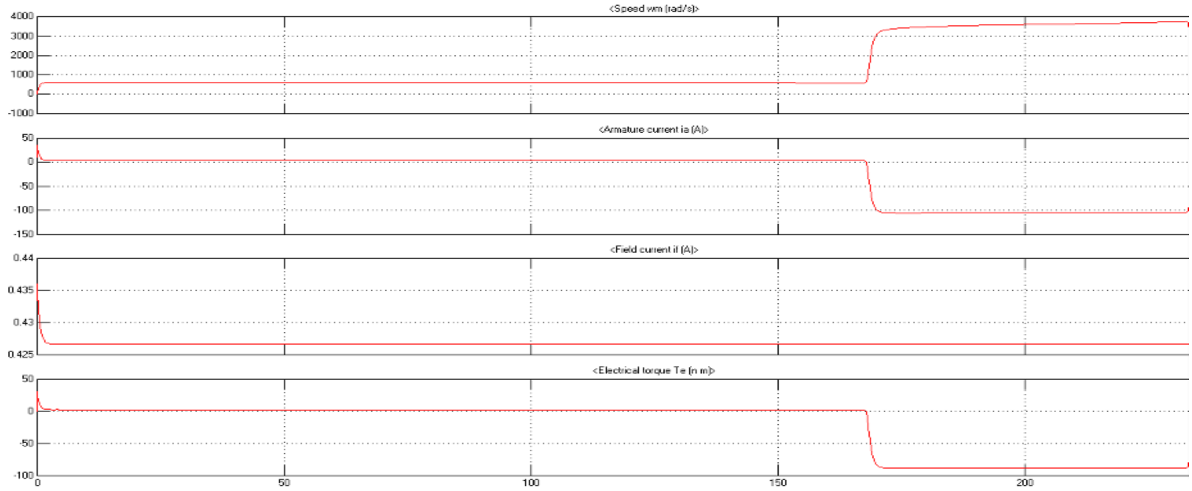

Fig.4.4 DC motor characteristics in Micro-grid

5. CONCLUSION

The proposed model of charging/discharging of energy storages in a renewable-energy based DC micro-grid model has been successfully verified through simulation results. The constant current controlled scheme has been shown working satisfactorily for loads and failure of one micro source in islanded mode. The transients arising from switching of loads or micro sources are eliminated in few cycles. The requirement of maintaining constant DC voltage is realized, considering different operating modes in islanded operating and grid connected states.

In order to achieve the system operation under islanding conditions, and considering battery SoC(%) and battery power limitation , constant current controlled source is proposed. DC voltage levels are used as a communication link in order to coordinate the sources and storages in the system and deeds as a control input for the operating mode adaptation during different operating conditions. System simulations and experimental tests have been tested in order to validate the proposed control method.

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