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POWER MANAGEMENT SYSTEM WITH GA CONTROLLED MULTI STAGE DISTRIBUTION CRITERIA IN SOLAR PV CS WITH FLYWHEEL ESS

Prakash Narayan Tiwari
Department of Electrical and Electronics Engineering, Rabindranath Tagore University,
Bhopal, India, prak.tiwari14@gmail.com

Dr.Anil Kumar Kurchania
Department of Renewable Enegry, Rabindranath Tagore University, Bhopal, India
anilkurchania@gmail.com

ABSTRACT

Solar energy, wind, and hydro are cost-constraint renewable energy sources that are useful in fulfilling the energy requirement. The development of EVs has driven due to the good progress in lithium-ion battery. Owing to their clean energy usage, electric vehicles (EVs) have attracted much attention. Moreover, the challenge is regarding the cropping up number of EVs that scales up an electric power's big demand, due to which the power grid load will be aggravated. In order to charge EVs, this leads to an exploration for clean and alternative sources of energy. To erect a charging station for EV application, solar energy system has been implemented by this project. With the provision of a constant voltage DC bus, multi- port charging has been employed by the charging station. Based on the concept of constant current/constant voltage charging and Power balance, the charging controllers are operated. The charging Station (CS) has been developed with a solar energy source of 25KW in MATLAB. The energy sources are connected with Local DC loads. AC loads via AC to DC converters and the energy storage systems (ESS) selected for study are flywheel ESS and battery connected in hybrid mode. The power flow across the DC line developed is controlled through genetic algorithm based multi stage distribution approach modified with Fuzzy Logic controllers. The output wave forms quality has been studied and artificial intelligence-based converter approach has been found to be apt for the optimization of process of multistage distribution as the energy stored in fly wheel is optimised to drive loads at all the ends with better power quality.

Keywords: Charging Station (CS), Genetic Algorithm, Fuzzy, Battery, Electric Vehicles, DC/AC converters.

1. INTRODUCTION

For the purpose of continuous development, a driving force that is apt in modern society is Energy. Nowadays, energy demand is extraordinarily high in this fast-moving world. The transformation of energy structure is prompted due to the issues related to energy crisis, increasing energy demand, and continuously aggrevating environmental problems. Renewable energy resources' increasing penetration, and electrical networks' distributed generation (DG) accelerates new energy paradigms like, charging stations and microgrid. A smart grid-based charging station (CS) in absence of energy storage is like a computer system without a hard-drive [1]. Energy storage is unavoidable and it employs as an energy buffer which can alleviate the coupling and imbalance between energy consumption and energy production in a Charging station [2]. The Charging Stations and its control is advancing promptly with increasing of transmission line numbers and production units and has become the research's area of interest. [3]

For the purpose of producing energy via conventional methods, they are arousing the issues of carbon dioxide's higher emission, power quality, and market deregulation. Because of this, the control, protection and the management of the CS has become complex. Hence, feasible options to the conventional methods for scaling down of the issues are renewable energy sources (RESs) and distributed generations (DGs).[4] Furthermore, due to the RESs' periodic nature, challenges occur while supplying energy over a period of time with minimum deviation still persists in CS.[5]

Today, demands are higher for a cost-constraint, dependable, eco-friendly, and durable ESSs. [6] The FESS can fulfill demands under high energy and power density, rapid response, and higher efficiency [7] Different reviews have been presented on flywheel-based ESSs by the authors.[8] In order to charge EVs in remote locations, a remote or standalone hybrid PEV charging station is utilized with the use of energy that is solely produced from individual renewable energy resources in absence of any interlink with the traditional grid systems. A focused analysis based on efficiency lifespan, energy density, self-discharge rates, life-cycle, specific power, scale, investment cost, application, environment impact, and technical enhancement among all ESSs has been carried out. Under mechanical ESS, FESS, along with PHESS and CAESS are categorized [9].

For the purpose of electricity generation, this system is useful. It also has storage for covering up the unpredictability of these REs along with a charging time improvement. Four major categories are consisted by the electric vehicle charging station's infrastructure, they are as under: 4-types of charging stations described as under: (1) charging with REs, ESS, and grid integration, (2) charging without ESS, (3) charging with ESS, and (4) charging with REs and ESS without grid supply [10]. In [11], an explanation is given about the configuration of ESS in EV charging stations with REs also ESS with grid supply.

In 1784, during industrial revolution, "Flywheel" word came across. Flywheels are utilized on boats and steam engines and also function as energy accumulators. [12] Around an axis, a spinning mass has been comprised through a mechanical battery, popularly known as Flywheel. Through the Spin of a rotor at extremely high speed and then storage of energy in the device as rotational energy, the flywheel operates. The rotational speed of flywheel is alleviated with the removal of energy from the device, as an output of the energy consumption theory. [13]

Even though people did not consider the electric vehicle as the primary vehicle, a few years ago, then also, hybrid as well as electrical vehicles are being utilized as primary vehicles. With the increment in the shares of hybrid and electric vehicles in the market also the electrical demand that depends on hybrid and electric vehicles is elevating considerably, as well. The grid load that is affected by the electric vehicles, elevates per day because of the increment in the plug-in hybrid vehicles and electric vehicles on roadways. Along with them being used for individual purposes, the hybrid and electric vehicle are popularly utilized for the purpose of commercial and public transportation as well.

While hybrid vehicles don't have any issue with regard to their range, electric vehicles still have a problem of range. A battery-module with high-capacity is needed by higher range and this problem elevates the vehicle cost. In order to solve this issue, fast charging plays a substantial role. High-power energy demand is needed by fast-charging and this greater demand is a significant grid load issue. For the reduction of this higher demand, an important role is played by energy storage. One of the high-capacity solutions that are consisted by energy storage devices for the: alleviation of losses in the system, increment of the effectiveness of the system, reduction of peak energy demand, and to balance a mismatch in the energy demand and supply. Being one of the mechanical energy storage types, Flywheels are getting utilized for low period electricity storage and high-power purposes. With their development, flywheel technology has become a substantial energy storage strategy and are being utilized in various sectors.[14]

One of the primary contributors to the carbon dioxide generation and its emission, is the transportation industry that also includes the oil and gas transportation industries, of which the share of technological transportation is 40 percent and for specialized transportation , it is 60 percent [15][16]. Henceforth, in recent years, the electrification of transporation has conceived more attention [17][18]. With regard to the effect of elevating electric vehicles numbers on the alleviating emissions of carobon, several studies have been conducted [18][19][20].

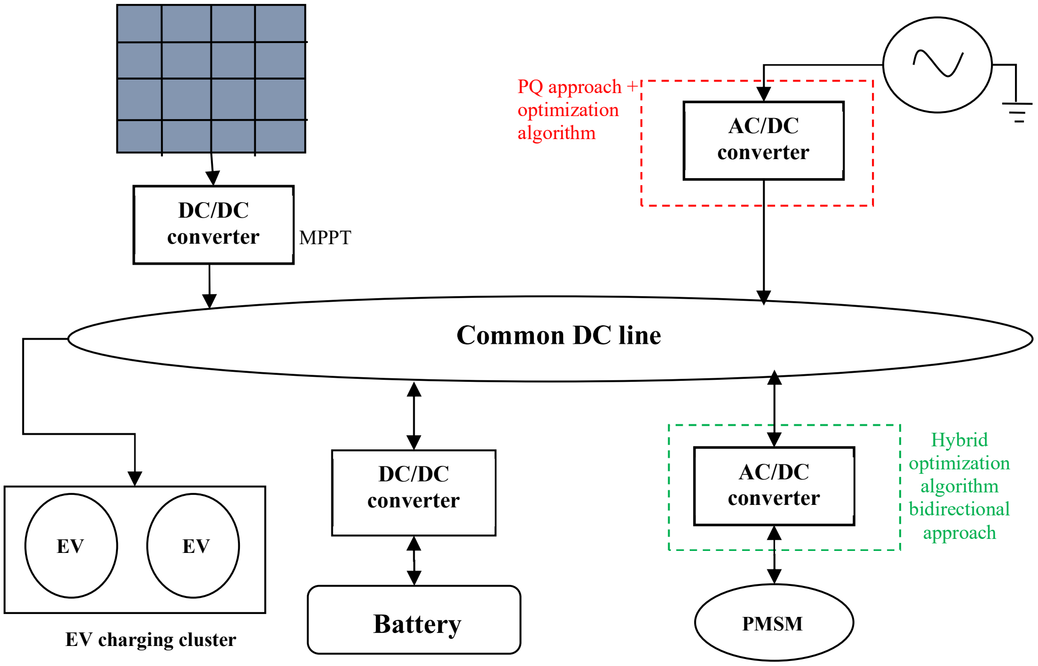

Figure 1: Proposed controls at the AC/DC conversion system in the EV model at the DC micro grid

This works gives takes an AI assisted CS power management scheme in combination with the fuzzification rules for applications in power systems and its control during the EV charging station development whose architecture is described in figure 1. Because of the power electronic systems' specific challenges and characteristics, for instance, control's high tuning speed, high sensitivity in condition monitoring for the purpose of aging detection, etc., the implementation of metaheuristics algorithms based on AI in power electronics has still areas left to be explored for further improvement. The AC/DC control designing at the grid end has been proposed with a PQ approach in combination with the metaheuristic algorithm for the improvement of the grid side system parameters. In order to ease the elemental parts' study and their respective changes, the designing can be done in dq0 reference frame. As per requirement, the system shall continuously keep checking the variable parameters and updates.

2. PV SYSTEM SIMULATION AND DESIGN ASPECTS

For determining the PV's electrical properties, which provides power to interlinked system, requirement is there to analyse how a variable load affects the PV cell's voltage and current. While a PV cell is modelling, an adequate no. of PV cell groups (NS) are linked in series, for the purpose of generation of needed output voltage. Also, for generation of needed output current, an adequate no. of PV cell groups (NP) are linked in parallel. On the light intensity and temperature, the equivalent circuit's PV cell variables are dependent. Hence, for the purpose of output power calculation, the values of temperature and light should be known. The PV cell is examined as depicted in figure 2. Depending on its current, the PV cell voltage can be attained with the use of Eq. (1). "I_0" is depicted as diode's reverse saturation current.

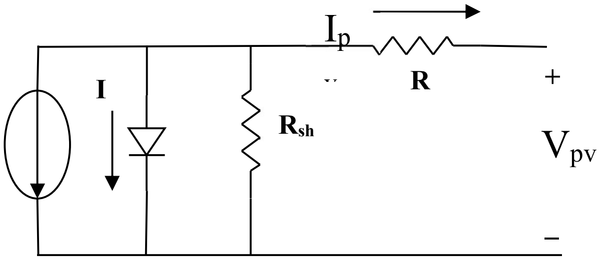

Figure 2: Equivalent circuit of solar pv cell

$$V_{cell} = \frac{A \times k \times T_{cell}}{e} \times \ln\left(\frac{I_{ph} + I_0 + I_{cell}}{I_0}\right) \quad (1)$$

T_{cell}, i.e., the PV panel cells' operating temperature changes while the solar radiation level and climate temperature vary. So, a new output voltage and a new photocurrent are generated. Due to the dependency on Solar radiation level and temperature of environment, PV cell's operating temperature varies. T_x ,i.e., the variable ambient temperature influences the photocurrent and the output voltage of cell. Equations (2) and (3) shows the voltage and current coefficients (i.e., C_{TV} and C_{TI}) of these affects the cell model, respectively.

$$C_{Tv} = 1 + \beta T \times (T_a - T_x) \quad (2)$$

$$C_{TI} = 1 + \frac{\gamma T}{S_{cell}} \times (T_x - T_a) \quad (3)$$

Where, due to the temperature, into the cell voltage and current, the changes slope of changes are represented by the β_T and γ_T coefficients respectively. The known reference ambient temperature and the different ambient temperature at different points during the tests are represented by T_a and T_x respectively. For the PV-SPP model in this study, the T_x value is taken as 28 °C. Depending on the PV cell type, the β_T and γ_T coefficients vary, and are determined experimentally. γ_T is computed between 0.02 and 0.1 and β_T is computed between 0.004 and 0.006 [25].

Due to the proportion of sunlight and the cloudiness of the sky, the solar radiation changes effectively, although, throughout the day, the ambient temperature doesn't change substantially. PV cell affects the photo current, the output voltage, and the operating temperature. These effects are described by Equations (4) and (5), and the output voltage (C_{SV}) and the photo-current (C_{SI}) , respectively.

$$C_{sv} = 1 + \beta T \ \times (S_x - S_{cell}) \quad (4)$$

$$C_{sI} = 1 + \frac{\gamma T}{S_{cell}} \times (S_x - S_{cell}) \quad (5)$$

PVs behaviour as the ideal source of current, are the assumptions for model derivation. Additionally, under the continuous conduction mode (CCM), all power converters are usually operated and the harmonics are ignored as well.

The responsible converter for driving the PMSM, and controlling its angular speed for different load torques, is AC/DC converter. Because the wheel motor is a PMSM (permanent magnetic synchronous machine), the electromagnetic torque is expressed in d-q rotating frame is shown through:

$$T_e = \frac{3p}{2}[\Psi_{PM} i_q + i_q i_d (L_d - L_q)] \quad (6)$$

where p is the number of pole pairs; Ψ_{PM} is the flux produced by the permanent magnet; L_d and L_d are respectively the direct and quadrature components of the wheel motor inductance. i_q is the quadrature axis current and i_d is the direct axis current. The work focuses on the converter system and the control logic for regulating the battery discharging process and the PMSM rotational speed. Emphasi are given to the overall energy management of the system. The converters and their control are very important in the system. They regulate the functionality and safety of the different components, and are responsible for a part of the losses in the driveline, requiring careful design.

3. WOKING METHODOLOGY AND SIMULATION

For the purpose of equations balancing and quality improvement in a charging station that is fed by renewable energy power resources, a new metaheuristic method that has GA optimized weights in combination with fuzzy logic controller has been proposed. A block model of Fuzzy logic and developed genetic algorithm could be readily modified to several systems and saves time while the systems get designed. Fundamental element of the 2-D (two- dimensional) space DQ reference is known as control error E, which is being used for analysis that is the difference of this error in a sampling process. Through the entrance of model content into the controller, there is a possibility to make changes that are provided by developed approach.

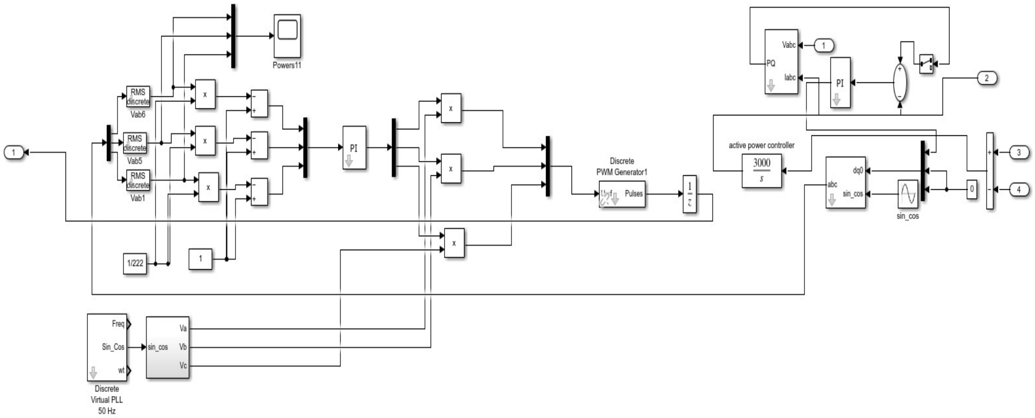

Figure 3: Control Logic Implementation in solar based CS

The multistage Distribution Genetic algorithm (MS_GA) parameters chosen for the fuzzy optimization in a process followed in **the figure**. The new proposed CS control architecture's fuzzy model and the MS_GA flow diagram's input and output blocks are presented. The composition of these functions of fuzzy membership is a significant step for the fuzzy space's input and output sections, is. For this purpose, triangular membership function equation is illustrated,

$$\mu(x) = max\left[\min\left(\frac{x-x_1}{x_2-x_1}, \frac{x_3-x}{x_3-x_2}\right), 0\right] \quad (7)$$

Here, the precise parameters for the purpose of determining the triangle's region and location arex_1, x_2, x_3 [34]. In both the processes of fuzzification and defuzzification operates this triangle membership function. For the composition of FLC algorithm via MATLAB-Simulink, explicit information has been given by Altas and Sharaf [34]. In this analysis, for the control that is based on the new proposed genetic algorithm, the needed weights were independently determined the error change DE, error E and the defuzzification membership functions. The MS_GA got utilized in each simulation, the process was repeted for this purpose. Depending on the value of error that is derived from each iteration and the GABL, the new weights, Wre f−DE, and Wre f−DU have been determined. With the use of these values, the stability changes and system response have been observed, for later iteration. In order to alleviate the issue of system getting slow down, a rule table with six has been utilized rather than seven rules, that is a combination of the GA and the fuzzy, so the function of fitness needed for the solution has been administered in alike means.

The aims and limitations of multi-stage distribution issue are described by mathematical formulations. There are I stages and each stage i has distributor unit j a number of J. Each unit distributor j has vehicle v with total V is utilized to dispatch the items. Every distributor unit j has the potential Cp for item stocking and any vehicle v has a capacity of Vcp and fixes cost Co.

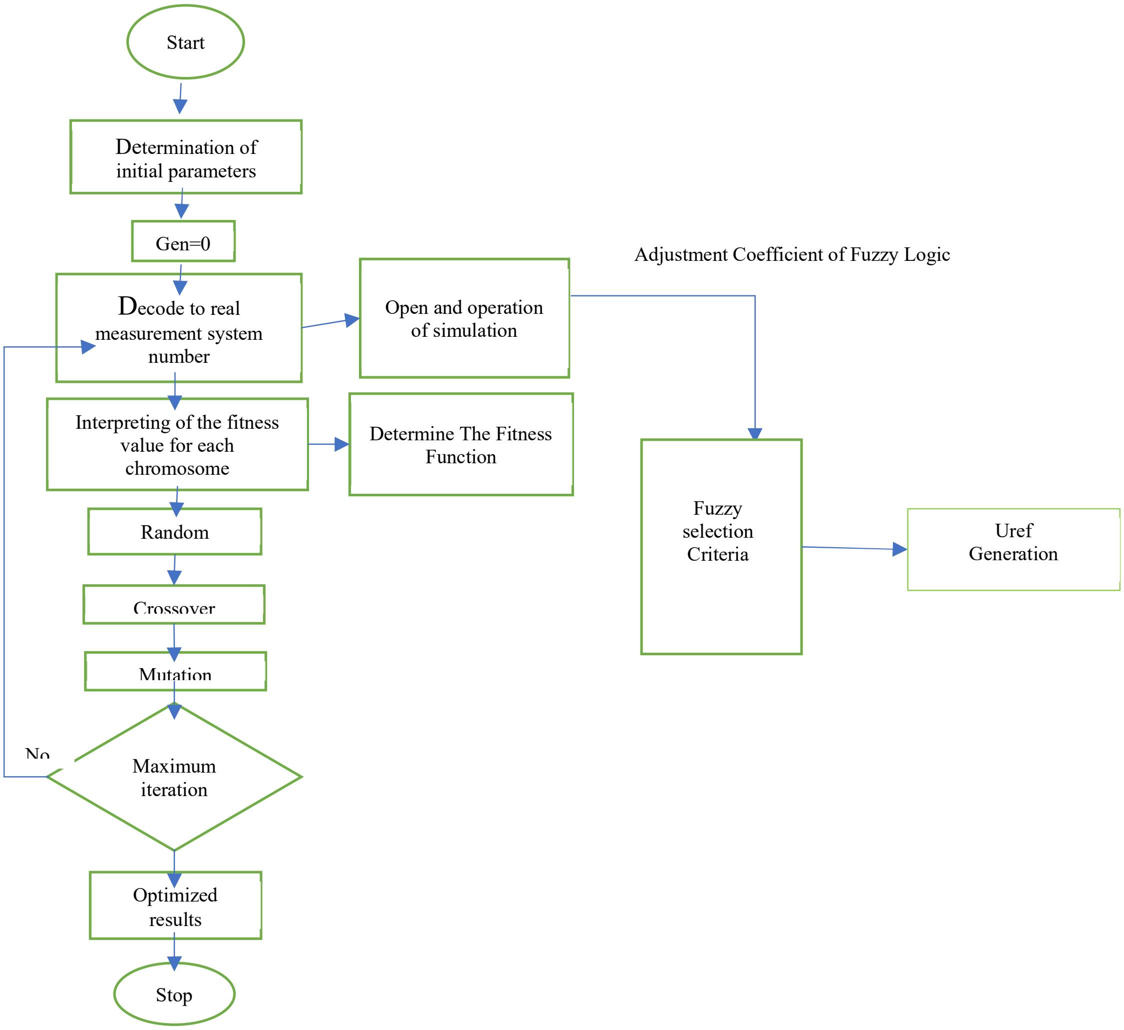

Figure 4: Algorithm formulation and implementation chart

Every distributor unit R which appeals amount/service by distributor unit at the stage above and far also to know which the distributor stage which answer to the order indicated by the status of St. 1 on St depicts which distributor stage answer the order and vice versa for 0. The objective function if the issue faced is to mitigate the variations, in the process of distribution [21]. Due to the reason that it alleviates the instability and thereby cost needed for the installation of separate device, for this to be the solution to the multi-stage distribution issue. Eq. (1) formulates the objective function.

The overall items unit that are sent from stage i by distributor unit j to distributor unit r, are represented by Xijr After that, Coijr is fixed cost for the delivery of distributor unit j to distributor unit r. Status of the distributor stage i in the request of service, is Sti.

From the power electronics standpoint, for an EV the on-board charger consists of an AC/DC power converter and some components of filter on the grid side and a bidirectional AC/DC converter at the PMSM based storage unit in the system. Consolidation of charger unit with motor drive is an effective solution for making a high-power density system. These units when controlled effectively can bring about changes in the system performance quality. Thus, the proposed Genetic algorithm-based approach has been further modified with fuzzy rules to account for better selection criterion and optimised results.

4 RESULTS AND DISCUSSION

Charging station with solar energy as input resource of 25KW has been proposed and developed in the MATLAB/SIMULINK. The charges station designed has two storage devices, fly will energy storage systems and battery storage systems. During modelling there are two types of loads that are considered DC loads of 5KW and 2 AC loads of 5KW each. For AC loads DC/AC inverters are employed which whose outputs and power are being controlled by the proposed genetic algorithm operated for the logic controllers. For providing power to electric vehicle batteries are linked to the system through a unit directional DC to DC controller. Recorded outputs are being studied for fluctuations and total harmonic distortions in case of AC loads. For a storage capacity of 5 kilowatt, the flywheel energy storage systems are modelled. The battery selected for EV have initial SOC percentage at 60%.

The system was analysed for power outputs by converter controls mainly in the two cases. In the first case DC converters driving the fly wheel systems are driven by a standard voltage regulation techniques having PI regulators find in the second case the entire power flow has been controlled with a multistage distribution genetic algorithm whose final outputs are optimised by fuzzy logic controllers.

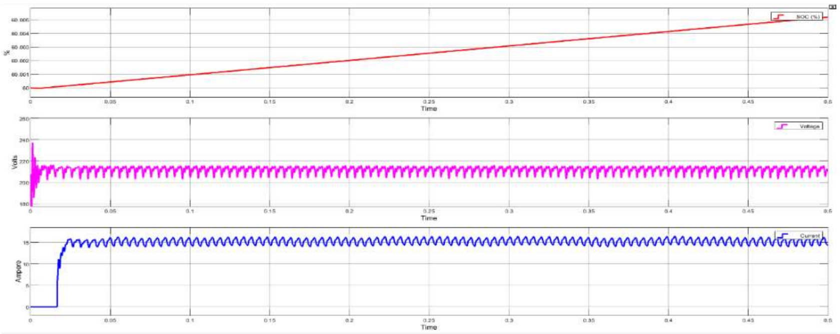

Figure 5: Storage battery response with solar output at full capacity with standard voltage regulation controllers for converters (a) SOC% (b) Voltage (c) Current

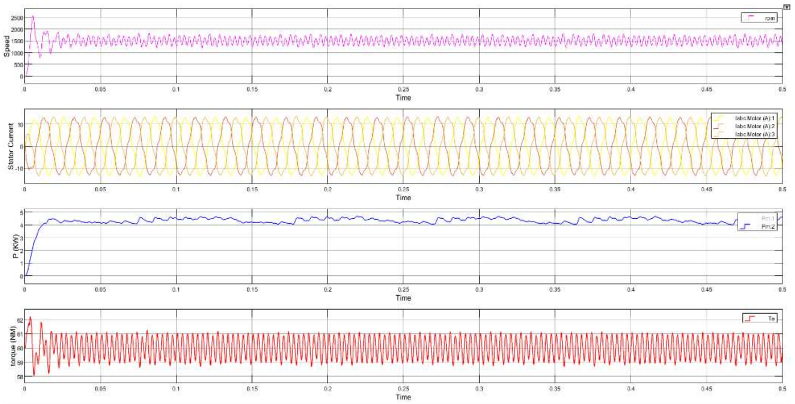

Figure 6 Flywheel Output response at the time of storage with standard voltage regulation controllers for converters (a) Speed rpm (b) stator current (c) Power in KW (d) Torque

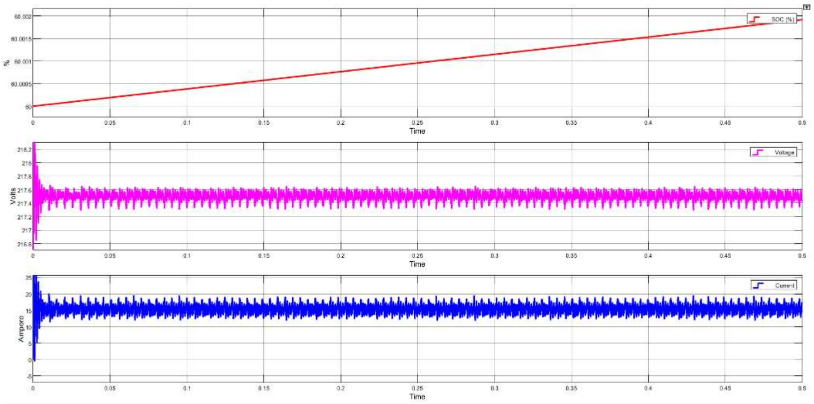

Figure 7: EV battery charging with solar output at full capacity with standard voltage regulation controllers for converters (a) SOC% (b) Voltage (c) Current

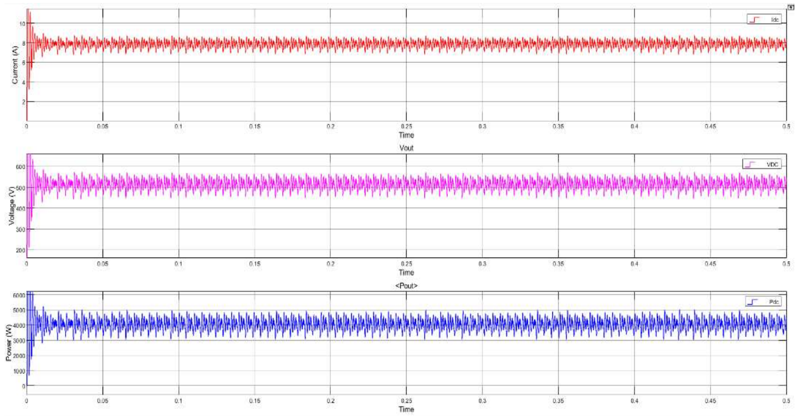

Figure 8: solar at full capacity feeding DC loads in system with standard voltage regulation controllers for converters (a) current (b) Voltage (c) power

The figure 5(a) depicts the ramp function showing the rise in the battery SOC% as an output of charging through DC link. The figure 5(b) and figure 5(c) are the depiction of the battery voltage and current at the full power delivery by the solar to the charging station. The FESS analysis with the system having basic voltage regulation method has been depicted in the figure 6. The Flywheel is observed to be rotating at a speed of 1500 rpm as shown in figure 6(a) drawing a stator charging current of 15 ampere in figure 6 (b). the rotational torque generated in the system with management with basic voltage regulation control is shown in figure 6 (c) and is found to be generating a power of 4.2 KW approximately.

Electric vehicle as a load is modelled with a battery with initial state of charge 60% and it shows that when the solar system is generating power at its full efficiency the state of starts to rise depicted in figure 7 (a). The battery voltage and charging current of EV has been represented by Figure 7 (b) and figure 7 (c). A DC load is modelled in the simulation using a resistance drawing a power of approximately 5KW which is shown in figure 8. Quality of the power drawn is seen to be slightly variable.

Now the charging station power flow control is changed and driven with genetic algorithm which works on the principle of multistage distribution and the final outcome is optimised by Fuzzy Logic controllers. The entire power flow from the system to the loads is controlled at the end of AC to DC converters driving the flywheel energy storage systems and allowing connection of DC link with the grid. The entire power flow system characteristics are kept same to match the basic power requirements by various loads.

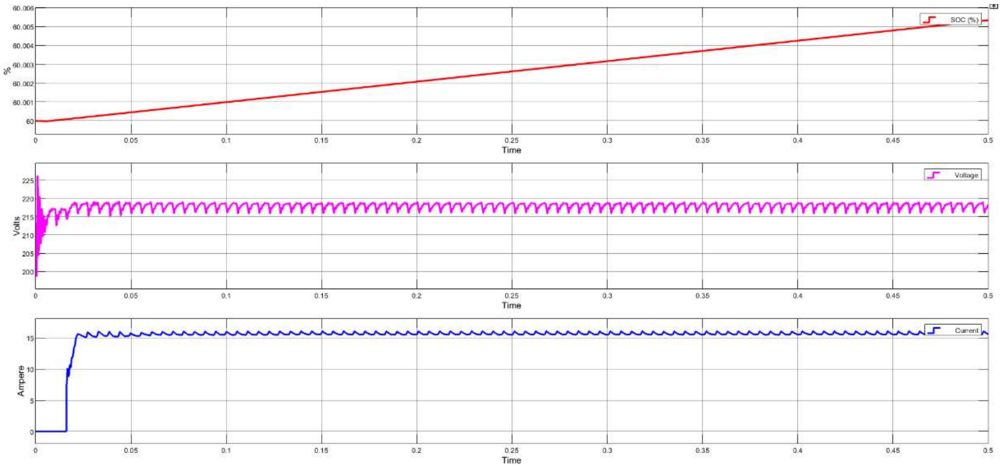

Figure 9: Storage battery response with solar output at full capacity and converters driven by MS_GA method (a) SOC% (b) Voltage (c) Current

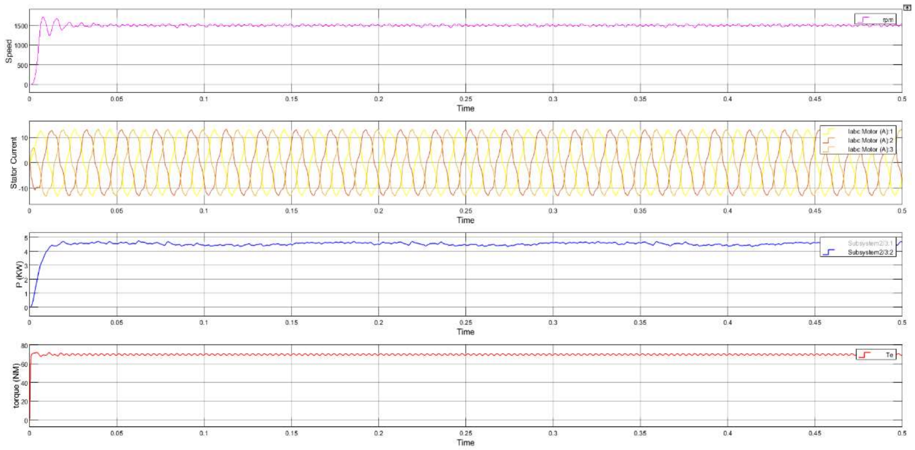

Figure 10: Flywheel power response with solar output at full capacity and converters driven by MS_GA method (a) Speed rpm (b) stator current (c) Power in KW (d) Torque

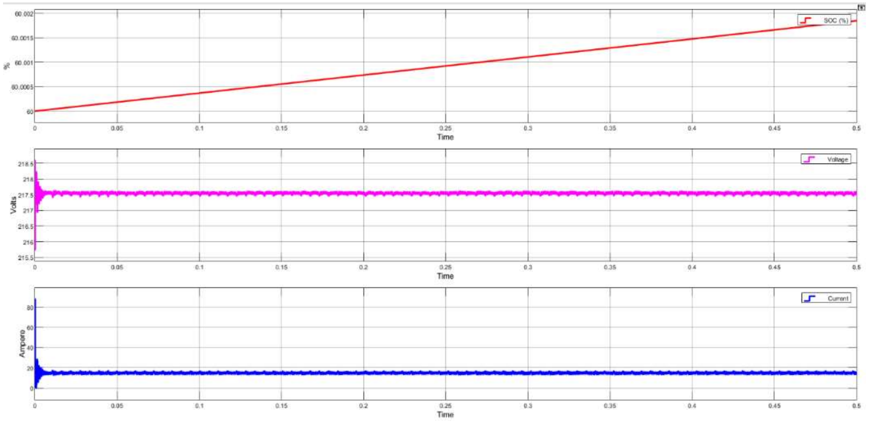

Figure 11: EV battery response with solar output at full capacity and converters driven by MS_GA method (a) SOC% (b) Voltage (c) Current

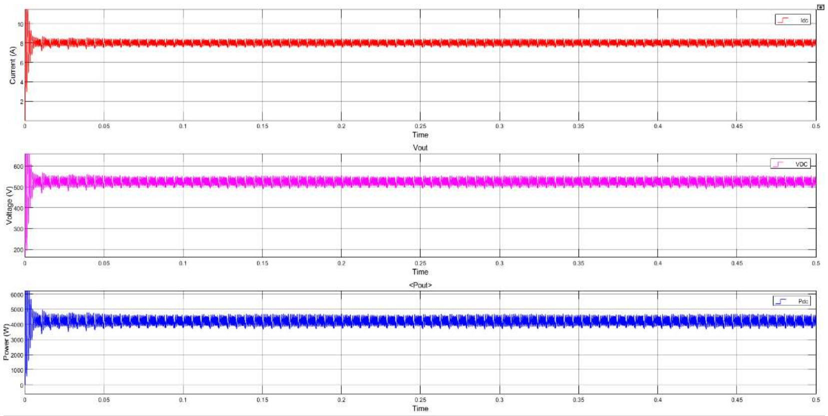

Figure 12: Solar at full capacity feeding DC loads in system and converters driven by MS_GA method (a) Current (b) Voltage (c) power

The analysis of the system has been done to improve the output power quality. The second case also sees that the storage battery is getting charged for 60% SOC as in figure 9 (a) and the associated voltage and current waveforms in the solar based charging station has been seen in the figure 9 (b) and figure 9 (c). The comparable outputs of the battery charging current shows moresmooth waveform when compared with the system having standard regulators. The ESS having flywheel which is rotating at 1500 rpm in a more stable condition is depicted in figure 10 (a). The figure 10 (b) depicts the charging current and the figure 10 (c) is the flywheel power which is close to 5 KW. The result of more stable output is the stabilized and improved input torque as shown in figure 10 (d).

The EV loads SOC% increasing and charging current with battery voltage is depicted in figure 11. The DC load when driven by the controlled having multistage genetic algorithm for power flow controls and further optimised by fuzzy controllers produced more stable output power as a result of better optimisation technique which is shown in figure 12. The AC loads also saw a reduced distortion in current waveform while they are driven at the AC load line. The THD% in the voltage was 1.04% and current THD% was found to be 4.40% in the solar based CS having standard controllers which was further reduced to 0.29% in the voltage and to 1.29% in the current waveform in the system having proposed ML_GA based optimisation approach. Thus the power quality issues at the AC load side was also seen to be reducing.

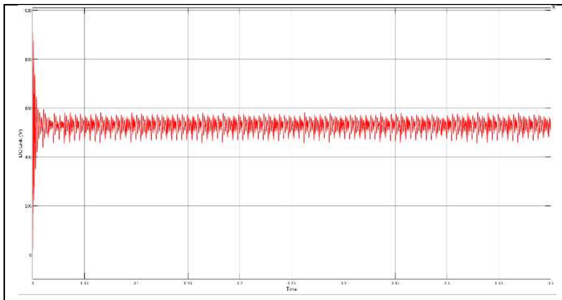

Figure 13: DC link voltage in solar CS with standard voltage regulation based controllers

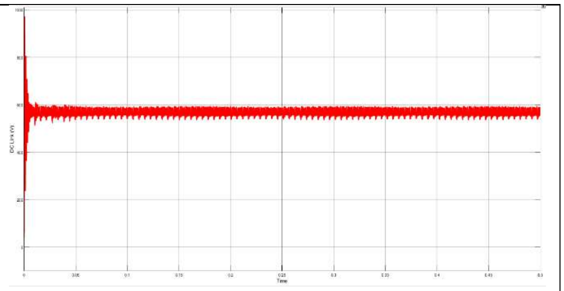

Figure 14: DC link voltage in solar CS with proposed MS_GA based converter control system

The DC link voltage is designed to be maintained at 600 volts. On observing the voltage in the system having standard voltage regulators based converters there was a variation in the waveform which is variable in between 550 to 600 volts as observed in figure. The waveform profoundly has peaks and dips while this link is reading power to various loads and energy storage systems. When the Solar base charging station power control is changed to the proposed AI assisted technique the stability in the DC link voltage was absorbed. The waveform is more smooth and the peaks has been reduced considerably. This will improve the power quality delivered at both the loads as well as ESS systems improving the life of the devices and system efficiency

5. CONCLUSION

A significant role is being played by charging technologies in energy transfer for an EV battery. For the purpose of providing good understanding about this technology, various converter levels, energy transfer modes, and techniques in addition to the standards currently being utilized for EV charging which was modelled with the use of MATLAB/SIMULINK. To effectively manage and dispatch the charging and discharging behaviour of EVs in the model, an AI based control strategy for the DC/AC converter operating in bidirectional mode is proposed. In conclusion, the charging stations' interconnectedness alleviated the power flow and stability problems brought on by solar energy sources. These observations show that the proposed MS_GA with fuzzy rules outperformed the controllers based on conventional voltage regulation in terms of efficiency for frequency stability. Furthermore, it was analyzed that the overshoot value of the suggested control technique was finer, and finally, proposed MS_GA with fuzzy rules would be prudent and advantageous for an interlinked CS with solar power sources and grid, since the operating costs, operating lifetimes, and effectiveness of the CS and devices connected to it are directly affected by the overshoot values and the settling time values.

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