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A fuzzy logic based control system Used to Improve Energy Production From Alternative Sources

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Abstract: *This concept presents a new technique to enhance the power production from an Alternative Source with DC-DC Integration method. It is found that switching frequencies that are integer multiples of the fundamental frequency should be avoided as they can cause the capacitor voltages to diverge. Suitable switching frequencies are derived for which the arm and line quantities will be periodic with symmetric operating conditions in the upper and lower arms. By product thus energy is connect into the grid by using the grid converter and used into user application. Thus, the practical outcome of this concept is a detailed description of how the switching frequency should be chosen in order to achieve advantageous operating conditions.*

Keywords: *fuzzy controller, photovoltaic array, Battery pack, DC/DC converter, voltage source inverter.*

1. INTRODUCTION

Power electronic converters operating from utility mains can generate current harmonics that are injected into the mains. The dramatic growth in the use of electrical equipment in recent years has resulted in a greater need to limit these harmonics to meet regulatory standards. This can be done by some form of power factor correction (PFC) to shape the input phase currents so that they are sinusoidal and in phase with the phase voltages. Three-phase PFC is typically done by using a six-switch converter either to process the bulk of the power fed to the load or to be an active filter that processes only a portion of the power fed to the load.

These structures were used to control a buck and boost converters, and the results were compared in terms of transient response, stability and robustness in steady-state regime. The findings indicated that the performance of the fuzzy controller was superior in all aspect when compared to the PID. However, as the boost is less stable than the buck, the overall performance of the PID and fuzzy controllers were at least similar. Moreover, fuzzy controllers have as advantage the fact that the knowledge of the small-signal transfer function is not required to design the controller, in contrast to PID whose mathematical model is indispensable to tune it.

Fuzzy logic is widely used in a machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as the "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans.

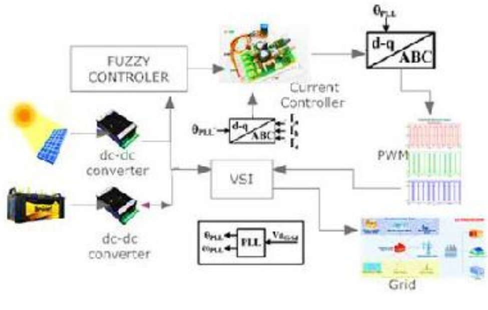

Fig. 1 Proposed system

Battery packs have been used with PV arrays to improve their efficiency and enable them to operate more stably under adverse conditions (variable level of irradiation). To enhance the performance of the PV array, step-up converters are chosen as power electronics interface to keep them operating as close as possible to maximum power point (MPP) what is achieved with the use of maximum power point tracking (MPPT) algorithms, and PI controllers used to synthesize the correct voltage reference calculated by MPPT algorithms at the PV array terminals.

Solar electric panels are made up of something called silicon, the same thing that makes up sand. There is more silicon on the planet than almost anything else. Even though you can find silicon almost everywhere, making a solar panel is difficult and expensive. The silicon has to be heated to super high temperatures in a big factory, and then formed into very thin wafers. When sunlight hits a solar panel, it makes electrons in the silicon move around. (Electrons are teeny tiny specks—they are way too small for us to see, even under a microscope.) The electrons flow through wires that were built into the solar panel. And presto! We have electricity! We can do whatever we want with this electricity, run a calculator, a CD player, or, if we have big enough solar panels, a satellite! [Solar panels are also called photovoltaic panels. "Photo" means light and "voltaic" means electricity.

This paper proposes a modified method to implement fuzzy and classical controllers to stabilize the operation of a RES tie-grid. In this figure, and are the gains of the voltage and current sensors whereas, and are the capacitance and inductance of the PV array input filter and represents the losses on To manage the charging and discharging of the battery pack a bidirectional buck-boost converter was used. As this kind of interface has different transfer functions for each operating mode, a variety of different controllers or an adaptive topology is needed in order to make it operate adequately. Because of these characteristics and the nonlinearities of the battery pack, a fuzzy P+I or a classical PI were employed as control strategies.

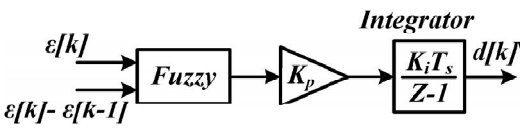

Fig. 2.1. Incremental fuzzy PD

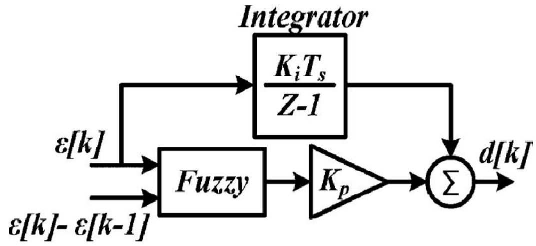

Fig. 2.2. Fuzzy PD+I

Following the aforementioned arguments, this paper pro- poses a modified method to implement fuzzy and classical controllers to stabilize the operation of a RES tie-grid. In the proposed approach, PV arrays with a MPPT algorithm and a voltage control are performed in order to keep them at the MPP. To regulate the terminal voltage of them are used a classical PI controller whose the system performance is enhanced with a battery pack.

To manage the battery-pack changing and discharging is used a fuzzy P+I and a classical PI controllers with the normalization of the input variables. The controllers are tested and compared with a double PI to determine what of them presented the best performance. It was also designed a fuzzy and PI controllers to stabilize the DC-link and inject into the grid the extra en- ergy produced by the RES. Additionally, the paper discusses a method to evaluate the variable gain of the fuzzy P+I by means of the classical control theories. Base on the theoretical anal- ysis, the controller with best performance was implemented in an experimental setup as will be described through the paper.

The paper is organized as follows. Section II gives a gen- eral description of the systems and includes a discussion of the main points related to DC/DC integration where are analyzed the DC-DC power converter models and the method used to design the PI controllers. Some information about the voltage source inverter (VSI) is also included in Section II, moreover this structure is not the focus of this paper, and more details about it can be found in [5], [6]. Section III describes the method used to design the fuzzy controllers and the performance of them in terms of step and frequency responses are also analyzed in this section. In Section IV, the results of the simulation are presented where a comparison of different control techniques for the bidirectional boost-buck converter and DC-link voltage control are detailed, and the experimental system with best performance are tested whereas, Section V summarizes the conclusions.

2. SYSTEM DESCRIPTION

Battery packs have been used with PV arrays to improve their efficiency and enable them to operate more stably under adverse conditions (variable level of irradiation) . To enhance the performance of the PV array, step-up converters are chosen as power electronics interface to keep them operating as close as possible to maximum power point (MPP) what is achieved with the use of maximum power point tracking (MPPT) algorithms, and PI controllers used to synthesize the correct voltage reference (Vref) calculated by MPPT algorithms at the PV array terminals (Fig. 3). In this figure, H_{v1} andH_{i1} are the gains of the

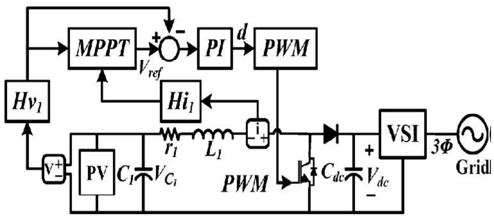

Fig. 3. PV array control diagram with an MPPT algorithm and PI controller.

To achieve flexible operation and avoid the requirement for a different set of fuzzy rules (fuzzy P+I controller) or different PI gains for each operation mode (current or voltage), the inputs are normalized by the set point to ensure the error stays between zero and one, Figure controller (A). To verify the system capability, the normalized structure was substituted by a double PI without input normalization (PI for current and voltage). Good performance can be expected for both modes of operation using a fuzzy strategy, i.e., the worst case in terms of performance will be at least equal to a classical PID controller. In pulse width modulator (PWM) output is switched from PWM 1 to PWM 2 depending on the direction of the current (PWM 1 for charging and PWM 2 for discharging), the reference is also switched according to the control strategy from to whereas C denotes the variable gain for a fuzzy.

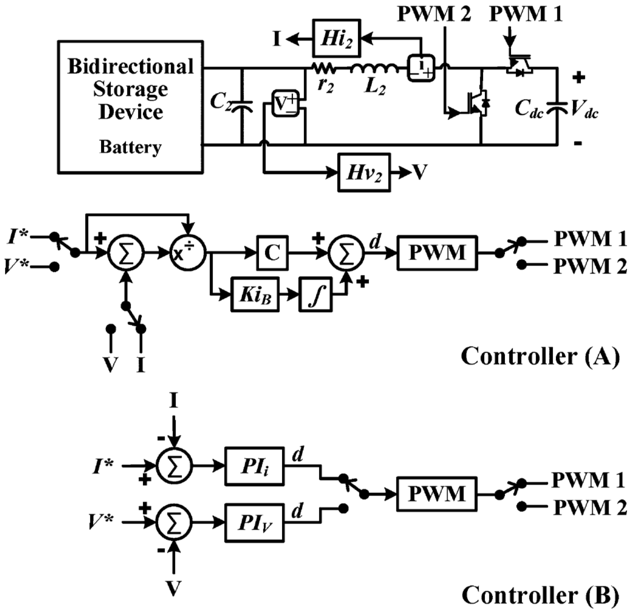

Fig. 4. Bidirectional buck-boost converter with different control topologies. Normalized fuzzy P+I or classical PI controller (A) and double PI controller (B).

In Fig. 4, the pulse width modulator (PWM) output is switched from PWM 1 to PWM 2 depending on the direction of the current (PWM 1 for charging and PWM 2 for discharging), the reference is also switched according to the control strategy from to whereas C denotes the variable gain for a fuzzy P+I or a fixed gain for a PI controller. In this figure are also shown the voltage and current sensor gains (Hv_2 and Hi_2); the capacitance and inductance of the bidirectional buck-boost converter (C_2 and L_2); and the L_2 losses (r_2). The integral gain (Ki_B), The PI controller for current (PI_i) And Voltage (PIv) mode of operation are Also seen in the figure

The fuzzy P+I and PI controllers were used to also regulate the DC-link voltage; however, the integral gain (Ki_{dc})and the PI gains need to be adjusted according to property system's transfer function that to the DC-link is determined, in general terms, for ($1/sC_{DC}$) and Fig. 6 shows the complete system, where the DC/DC converter controls the power flow from the RES and the VSI regulates the DC-link voltage by means of the power injection into the grid as shown as follows:

$$P_{Grid}=P_{Bat}+P_{Panel}$$

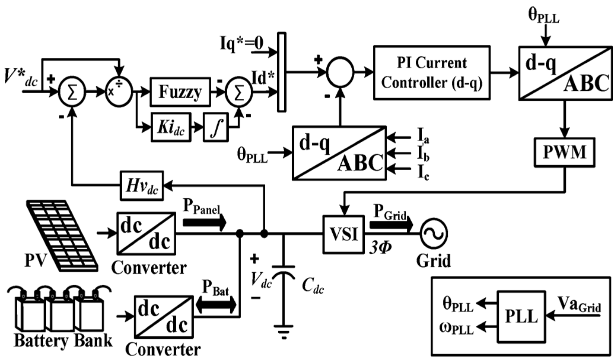

Fig. 5. Fuzzy P+I control system used to regulate.

A simple PWM-VSI is used to transfer the power produced by the PV arrays and stored in the battery pack to the grid. The VSI is controlled in the d-q synchronous reference frame by means of the classical transformation.

3. FUZZY DESIGN

Because of the stability limitation of the buck-boost and the switching control strategy (current control to voltage control), it was chosen to be used on the fuzzy P+I design. Other important aspect is regarding to the flexibility needed for some battery-charging methods, such as the two-step method shown in and illustrated in Fig. 6. This method involves a controlled current(I_{Max}) (phase 2) until the battery voltage reaches the maximum value defined by the manufacturer(Vst) (phase 3). At this point the system should keep the voltage constant to decrease the current. When the battery is fully charged, a constant fluctuation voltage(Vf) is reached to prevent battery self-discharge and keep it fully charged (phase 3). Phase 1 is used only if the battery has been deeply discharged. Furthermore, voltage-controlled charging mode is required to avoid a high voltage level applied to the battery terminals whatmay produce damage to the storage device.

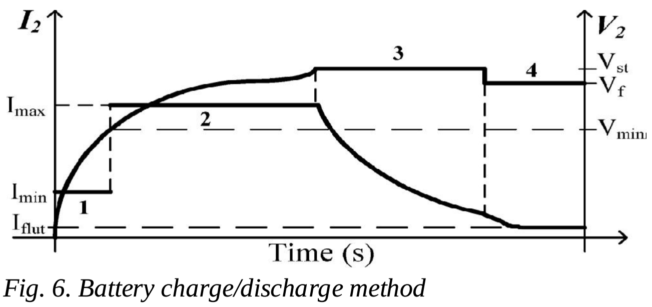

Fig. 6. Battery charge/discharge method

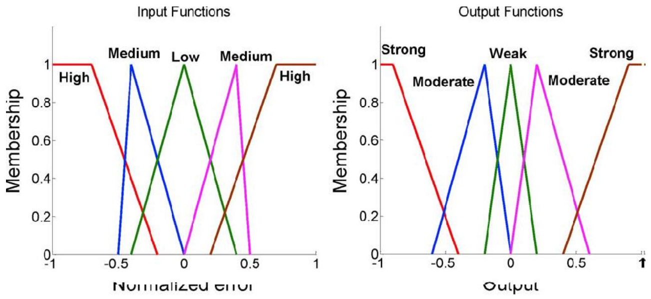

Fig. 7. Input and output membership functions.

A. Fuzzy Rules

where the authors used more than one input for the fuzzy system, in this paper only one input, the error was used. This simplifies the implementation of the fuzzy system without loss of performance and keeps the cost down as the greater the number of inputs the greater the computational cost. For the design of the fuzzy rules and membership functions (Fig. 8), existing knowledge of the buck-boost converter operating in the continuous-conduction mode and the DC-link voltage of the VSI with a classical PI controller were used.

In practical terms, all membership functions were adjusted based on the limits of the DC/DC converters and VSI. For boost converter, for the worst case, the maximum duty-cycle must be lower than 90% to avoid operation in the nonlinear region. Regarding to the PV array, the terminal voltage varies from 70%to 90% of Voc whereas to the battery pack the maximum current delivered is 10% of the battery capacity. When the buck mode is inferred, 10% of current continues as the maximum value allowanced however, in this mode of operation, the battery can be charged with at most 5% of over-voltage according to the manufacturer. In terms of VSI, the limits of operation are 10% of the DC-link rated voltage.

TABLE I. FUZZY RULES

Error	Output
Low	Weak
Medium	Moderate
High	Strong

The rules were defined according to Table I, making the system as fast as possible to compensate for a transient load or rapid change in environmental conditions.

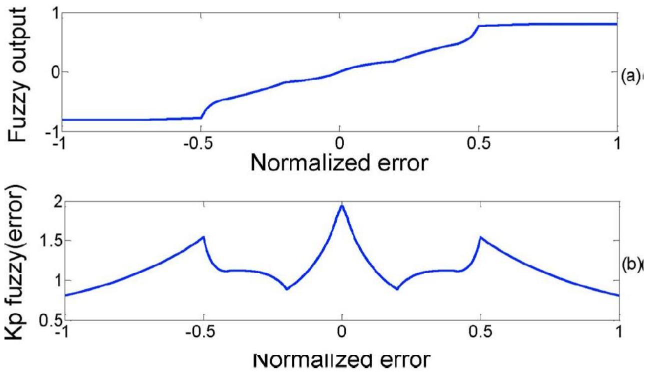

Fig. 8. (a) Fuzzy output and (b) Kp fuzzy as a function of the normalized input error.

4. SIMULATED RESULTS

In this section, the results of simulations are presented to validate the control technique discussed in this paper. The performance of the fuzzy P+I and classical PI controllers were compared in terms charging or discharging of battery pack, and DC-link voltage stability. All the simulations were performed in Matlab/Simulink® using a four-panel PV array and three series-connected lead-acid batteries to form a small integrated DC supply system.

A. Fuzzy P+I and PI Controllers Used With the Storage Device

To evaluate the system capability a set of tests was carried out. The integral gain of the fuzzy P+I controller was tuned using classical PI tuning with the aid of equation presented in Section II to be compared with the classical PI controller. Figs.11 and 12 show the performance of the three different controllers found in Fig. 5, the fuzzy P+I controller and the improved PI both with the normalization of the inputs [Fig. 5 controller (A)], and the double PI [Fig. 5 controller (B)]. All of them were subjected to the same situation, control switching from current to voltage and inversion of the current from charging to discharging or vice-versa. Initially, current control is active and a reference current of 4 A is maintained (as specified in the manufacturer's datasheet, phase 2 in Fig. 7). However, when the battery terminal voltage reaches 37.2 V (maximum voltage in phase 3) the control strategy is modified from current to voltage in order to avoid over-voltage and damaging to the storage device. After around 0.5 s the operating mode changes from charging to discharging because a heavy load is connected at the VSI terminals. It is important to note that when the current inversion occurs, the PV array is operating at the MPP, and the power, produced by it, continues at the same value independently of the battery operation mode. and a classical PI controller is employed to adjust the PV array terminal voltage. The decoupling control characteristics that prevent the battery control interfering with the PV array control and vice versa can readily be observed.

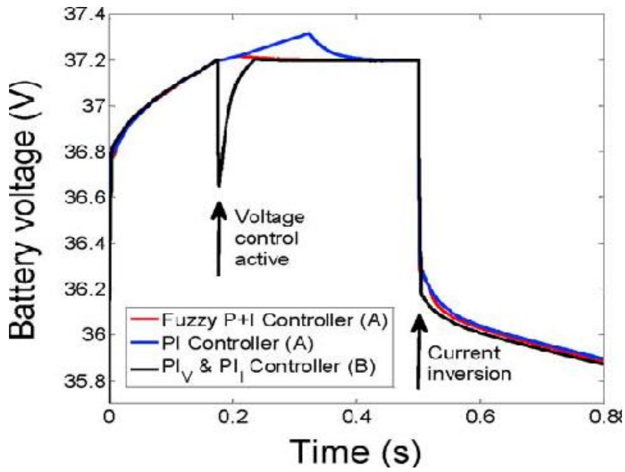

Fig. 9. Battery terminal voltage.

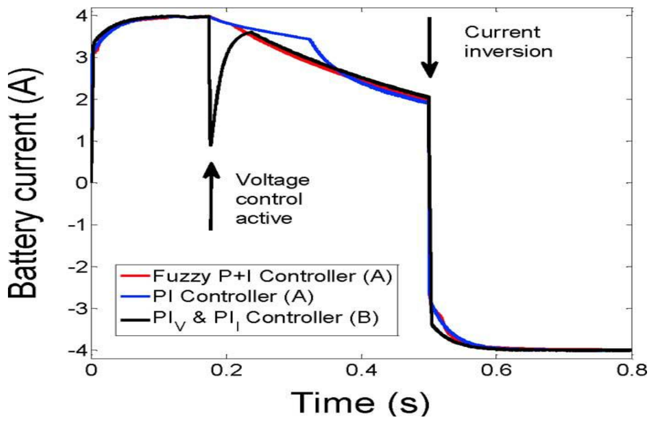

Fig. 10. Current flow through the battery.

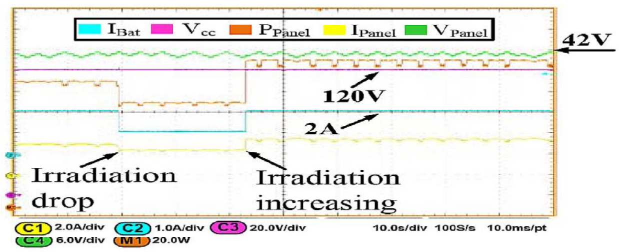

Fig. 11. System subjected to a step change in irradiation.

Fig. 12 shows the PV array output voltage and power when the array is being regulated at the MPP by the MPPT algorithm

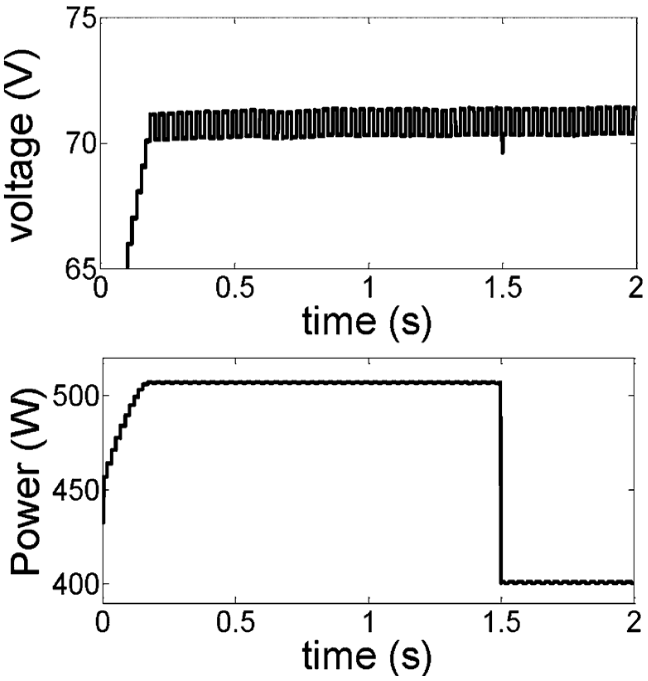

Fig. 12. Terminal voltage and power produced by the PV array.

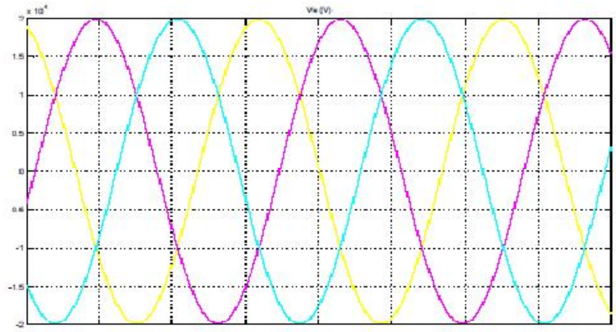

Fig13. 3-phase Output Voltage and currents at grid side.

5. CONCLUSION

A fuzzy P+I and PI controllers have been used to regulate the current and voltage at the battery terminals as well as, the DC-link voltage. Additionally, to improve the system performance a PV array associated to a searching algorithm plus a classical PI controller are used to keep the PV array terminal voltage at the MPP. A general mathematical model of the DC/DC converters was presented in order to design the PI controllers. Additionally, these models are used to design the fuzzy P+I in order to compare the fuzzy system with the normalized PI and double PI controllers. Similarly, the same procedure was adopted regarding to the DC-link voltage control. In terms of advantage, the fuzzy P+I presented a variable gain improving the system accomplishment in aspects as time stabilization and overshoot for the DC–DC converter. However, regarding to the DC-link voltage control both presented similar performance. In terms of analyze the step and frequency response of the system for a set of gain produced by the fuzzy P+I controller was done using the boost converter because of this sort of converter presents the lower level of stability.

In terms of simulation, the power balance was evaluated with different situations such as: control alteration, current inversion at the battery pack terminals, AC load maas well as, drop on the level of irradiation. The tests demonstrate that the voltage is lower than 1% for all control structures, whereas the current can achieve up to 15% when the PIs are used. Regarding to the DC-link, all control structures shown similar performance what make the use of either feasible. According to the theoretical controller performance, an experimental setup was built to show that the fuzzy controller could control the battery charging and discharging as well as, the DC-link voltage. Furthermore, in the worst case the system performance between fuzzy sets and PI controllers are similar

6. REFERENCES

[1] Renewable energy operation and conversion schemes,by G. Spagnuolo, G. Petrone, S. V. Araujo, C. Cecati.

[2] M. Datta, T. Senjyu, A. Yona, T. Funabashi, and C.-H. Kim, “A frequency control approach by photovoltaic generator in a PV-diesel hybrid power system.

[3] G. M. Masters, Renewable and Efficient Electric Power Systems.

[4] M. G. Simões and F. A. Farret, *Integration of Alternative Sources of Energy*.

[5] T. Gupta, R. R. Boudreaux, R. M. Nelms, and J. Y. Hung, “Implementation of a fuzzy controller for DC-DC converters using an inexpensive 8-b microcontroller.

[6] Design and tuning of a modified power-based PLL for single-phase grid-connected power conditioning systems