

Smart controller design for safety operation of the MEA electrical distribution system

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Abstract—as the electrical network of the future aircraft becomes more and more complex, there is a need to develop a smart controller that can enable fast and automatic decisions to be taken to protect the vital operations of the system. This work aims to show how a control strategy can be devised to ensure the safe operation of such an electrical power system (EPS). The case study presented in this paper demonstrates how a smart controller can be used to ensure the uninterrupted power supply to the high priority loads in the event of the failure of one to four power electronic converters. The control logics are developed using the finite state machine (FSM) method, and applied to a representative DC based EPS of the future aircraft. The results are verified in Simulink environment.

Keywords—MEA, AEA, Aircraft Electric Power System, HV270DC, Smart Network, Finite state machine

I. INTRODUCTION

There has been a rapid evolution in the electrical power capacity of the aircraft in the recent years. The Boeing 787 Dreamliner[1] with its electrical power system (EPS) of more than 1 MW and the fast trend towards the More Electric Aircraft (MEA) have brought new advancements in the aviation's history[2]. A key aspect of the MEA concept is that traditional pneumatic and hydraulic loads are replaced by electrical equivalents. The electrical systems have led to important improvements in the aircraft power system particularly due to the extensive use of power electronic technologies. The EPSs have higher reliability, controllability, efficiency; they are easier to replace or maintain and have lower carbon emissions [3, 4]. However, the safety issues as well as the potential of system optimisation related with electrification need to be further investigated. Extensive research is ongoing in this field, starting from studies on the fault tolerant, high power density electrical machines for electrical power sources application[5] to the new Dual Active Bridge converters (DAB) that can provide better solutions in terms of reliability and capability under bidirectional operations[6]. This paper addresses the safety of the MEA EPS. Moreover, studies on the use of either AC or DC type of the electrical system may play a key role in determining the next step towards the All Electric Aircraft (AEA). Recent studies have demonstrated the benefits of the high voltage DC systems (HV270DC). With DC systems, problems such as the skin effect can be eliminated and the performance of cables can be increased as shown in [7]. Further, the use of rectifier devices for the electrical instrumentations such as radars[3] will no

longer be required, thus leading to reduction of weight of the power system. This work is applied to a representative aircraft DC based electrical network. A fundamental step in the development of the aircraft EPS is to enable all the electrical devices on board to work at the safest and most optimal level. For instance in order to ensure high availability of electric power within the aircraft, the power network architecture should allow a potential redundancy of the certain power supplies as well as critical devices such as power converters. Vital loads should be powered under both normal and fault conditions. Energy storage systems, along with suitable power electronic interfaces, can provide a wide array of solutions to such key issues. The EPS can be designed to be have various energy configurations[8]. The electrical network can be managed, optimised and ensured safe under different operating conditions, and critical fault scenarios by using a smart controller. This paper develops a smart controller that manages the power flow in the EPS under critical fault scenarios of its power electronic devices, with the aim to ensure continuous power supply to the vital loads during these fault conditions. There are different ways to design the EPS controller, "C language", Fuzzy logic and Finite State Machine (FSM), as reported in previous studies in [8-10], as will be further discussed in section III in this paper. In this work, the controller is based on FSM theory. The FSM is a computational model, where the behaviour of the system can be modelled as a set of states and transitions[11]. There are advantages that are considered in the use of FSM for the design of the controller. First, it is easy to use due to the fact that it is a graphical language. Second, it contains fast and powerful algorithms[12]. The work in this paper is divided in six sections. Section II discusses how the power flow can be managed in the aircraft EPS. Section III outlines the methods that can be used to design the controller as reported in the literature and introduces the theoretical background of the FSM method that is used in this paper. Section IV presents a case study whereby a control strategy is developed for the design of the smart controller to ensure the uninterrupted power supply to vital loads in a representative MEA EPS in the event of faults in the power electronic converters. Section V implements the control approach to the representative EPS in the Simulink environment and discusses the results of the case study. The conclusion is presented in the section VI.

II. POWER MANAGEMENT OF THE AIRCRAFT EPS

The configuration of a conventional EPS for modern aircraft is shown in Figure 1. The EPS is supplied by 115 V line to neutral AC voltage with a line frequency of 400 Hz. With this configuration the electrical generators are connected to the main engines (in most cases each engine supplies two generators) via a mechanical drive[4], which is used to keep the mechanical speed and the electrical frequency constant on the electric bus. These are the primary electrical power sources.

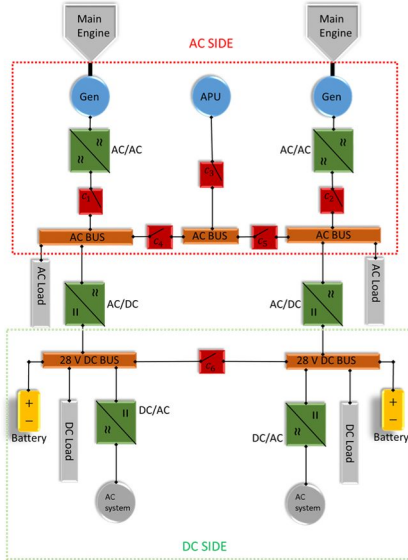


Fig. 1. Typical EPS of a conventional aircraft

The generators supply power to a set of ac loads through dedicated AC buses. These loads can be an induction motor driving a hydraulic pump or lighting. There are multiple buses in the aircraft to account for redundancy and for use during emergency operations. The AC buses deliver power to the DC buses through transformer rectifier units (TRU) as shown as AC/DC converters in Fig. 1. The 28 V DC buses are used for supplying the avionics systems on-board. In the new generation of aircraft such as Boeing 787 and Airbus A380 the variable speed constant frequency (VSCF) is replaced by variable frequency bus, which requires the power conversion for supplying different types of loads but introduces the advantage of operating motors at different speed so as to work at the optimal point. DC-DC power conversion is also needed for devices such as battery chargers [1]. While standard topologies for electric power systems are already complex, the next-generation aircraft EPSs are expected to become even more elaborate, making the design of such architectures more challenging. A step forward in the design of the EPS of the future aircraft is the use of HV270DC systems. An example of such a configuration is depicted in Figure 2. In the design of military aircraft and unmanned aircraft, HVDC systems are already used in order to cope with the high power demand of the system. The main idea is the use of an increased DC voltage, typically 270V dc, which is obtained from the conversion of 115 VAC through a transformer rectifier unit. The F-22 and F-35 both currently utilise HVDC[13]. There are two main advantages in the use of higher voltage level. First, it is possible to obtain 270V dc from a conventional generator, by means of a transformer rectifier

unit. Second, some equipment such as radars and direct actuator controllers, which are powered from 115Vac, have integrated blocks of rectification, that convert the 115Vac levels to 270Vdc; this can result in the reduction in system weight.

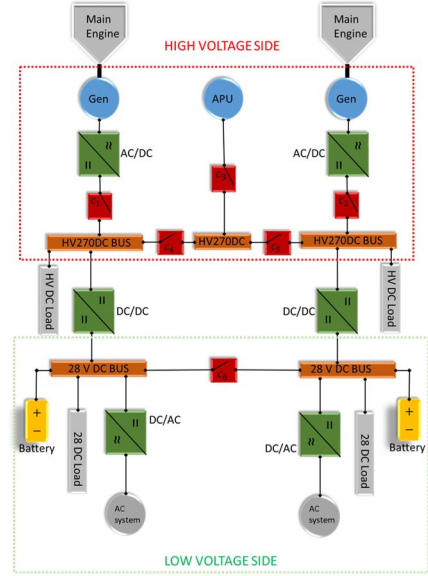


Fig. 2. An example HV270DC EPS for the future aircraft

In both configurations shown in Fig. 1 and 2, the buses are connected by tie-breakers, which are electromechanical devices for commutations of the EPS. These switches, labelled as c_1 to c_6 in Fig. 1 and 2, are used to control the flow of power and reconfigure the topology of the electric power system by establishing new connections between components. Changing the status of the contactors (open or closed) will result in different system configurations and will thereby affect the power level of different buses or loads. For instance, in the case of a generator failure, an auxiliary power unit (APU) or battery may be used to power some emergency buses to allow the safety critical operations. It is possible to devise a strategy for a controller such that it manages the power flow distribution by acting on the switches c_1 to c_6 setting new power paths and ensuring safe operation under different operating scenarios. In this paper, the control strategy is designed to help the main generators in the critical phases and supply the vital load in all the possible fault scenarios. Multiple approaches may be employed to design such a controller. The next section discusses the latter methods along the FSM which is the method adopted in this paper.

III. THEORETICAL BACKGROUND

For managing the EPSs through the use of a smart controller, it is important to identify the main objectives that the controller must accomplish and to define the corresponding rules that will enable the controller to carry out these functions. For instance the aim of the controller can be to provide uninterrupted power to a specified bus or load. In order to achieve such a goal, the controller can be given the tasks to reconfigure the system by switching on or off of a number of the contactors, based on the reconfiguration strategy[14]. However, rules must be established to avoid dangerous conditions such as creating

parallel power paths between two sources or discharging the batteries below a pre-set limit. The reconfiguration strategy is used to find the correct pathway to feed each load while taking into account the optimisation of the system in terms of power flow and avoiding unsafe configurations. Different methodologies for the controller design of the power system have been investigated in the recent years. As the EPSs for the future aircraft are becoming more intricate, the strategies for the controller are becoming more complex; the controller has to become smarter. Starting from the use of the C language, the methods are moving towards more intelligent programming languages like "C Language Integrated Production System" (CLIPS)[10]. These type of languages are used in the Knowledge-based system, which consist in the implementation of business and mandatory rules in a single framework. The basic structure of rule is made of two main parts, which consist of a condition part (IF) and action part (THEN). Whenever all the rule's conditions are fulfilled, the rule is satisfied. The main strength of the knowledge based system is its capacity to activate the rules whenever the conditions are fulfilled. Whereas this capacity is not provided in traditional procedural programming where conditions of an "if" test are evaluated at a particular point of the program. The priority level of each execution can be specified to each rule, so if several rules can be fired at the same time, the highest priority rule will be fired first[14]. Since the controller must be able to operate on the EPS applying a set of specific rules, these rules need to be expressed ("synthesized") in a mathematical language and translated for the processor. A first approach about synthesis of reactive systems can be found in [15, 16]. Moreover, due to the fact that the EPS can be seen as a reactive system the rules cited above can be applied. The Linear Temporal Logic (LTL)[17] can also be considered a good solution to apply in order to satisfy all the requests in the management of the EPS. LTL is an extension of propositional logic that incorporates notions of temporal ordering to reason about correctness over a sequence of states. In reactive systems (i.e., systems which react to a dynamic, a priori unknown environment)[18], correctness will depend not only on inputs and outputs of a computation, but on execution of the system as well. Temporal logic is a formalism well-suited for these types of problems in which the system must react to an adversary or environment. This paper uses the FSM which combines "Knowledge-based method" and LTL notions. FSM can be considered a suitable tool for the design of the control logic. Basically, FSM is a computation model that can be implemented with hardware or software and can be used to simulate sequential logic. FSM can be used to model problems in many fields including mathematics and artificial intelligence. In a FSM the behavior of the system can be modelled as a set of states and transitions between states, these systems are known as reactive systems[11]. In mathematical notations, the FSM can be expressed as:

$$f(\Sigma, S, s_0, \delta, F) \quad (1)$$

In equation (1), Σ represents a finite set of symbols (as variables of the system), S is a finite set of states, s_0 is the initial state, such that $s_0 \in S$, and δ is a state transition function defined in equation (2) and F is finite set of final states.

$$\delta: S \times \Sigma \rightarrow S \quad (2)$$

An example of the formulation (1) is depicted in Fig. 3.

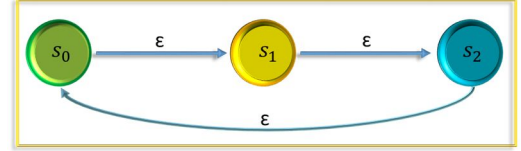


Fig. 3 Example of a reactive system

The following equations describe the system in Fig. 5

$$\Sigma = [\epsilon] \quad (3)$$

$$S = [s_0, s_1, s_2] \quad (4)$$

$$\delta = [s_0/\epsilon \rightarrow s_1, s_1/\epsilon \rightarrow s_2, s_2/\epsilon \rightarrow s_0] \quad (5)$$

$$F = s_2 \quad (6)$$

The FSM approach is applied to the case study in section IV of this paper.

IV. CASE STUDY

This section develops a controller which has the main task to ensure the uninterrupted power to the vital loads under fault conditions based on the Finite State Machine (FSM). The controller strategy is tested and validated in simulation in the Simulink environment.

a) Aircraft EPS model

The study is demonstrated by applying it to an example EPS of a future aircraft as shown in Fig. 4.

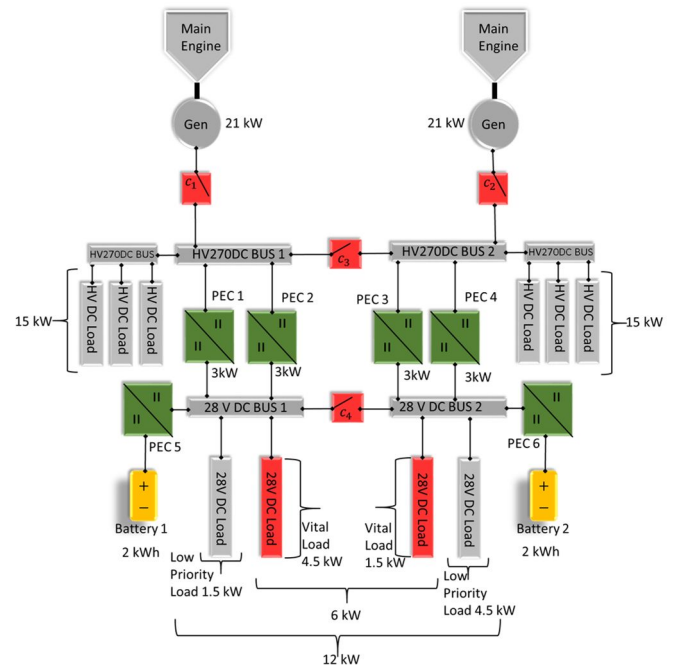


Fig. 4. Circuit diagram of the EPS under study

The electrical network shown in Fig. 4 is a good example of the MEA concept with a HV270DC system. It is composed of two main generators of 21 kW each. These generators provide power to two sets of high voltage (HV) loads of 15 kW each through two HV270DC buses, and four sets of low voltage (LV) loads of 6 kW each through two LV28VDC buses. The two out of the four LV loads are vital high priority loads that require uninterrupted supply of power. The four DC/DC converters (PEC 1 to 4) rated at 3 kW each, are bidirectional, and allow power transfer between the low voltage and the high voltage side, thus increasing the availability of power in the entire EPS. These four converters can be controlled in order to adjust the power delivered from the generators to the loads. Of note is that the power converters are connected in couple between the HV bus and the LV bus as shown in Fig. 4. This design introduces redundancy in the power system, which is beneficial for managing fault conditions and power flow within the network. The low voltage side of the EPS consists of two batteries of 2 kWh each, sized from commercial values[19]. They are connected to the low voltage buses through DC/DC converters, which are used to maintain the value of the bus voltage at 28 volt. It is to be noted that the devices of the electrical network in Fig. 4 have been modelled as ideal components in Simulink environment, as the focus of the study was to verify the logic operations of the controller.

The power converters are sized in order to transfer power to the low voltage side under the normal operations. In case of emergency such as the failure of one of more 3 kW DC/DC power electronic converters, the battery can be employed to supply the surplus of requested power, especially to the vital loads. This can be achieved by designing a smart controller as will be discussed in the next section.

B. The control strategy

The controller is designed to ensure the safe operation of the EPS by supplying uninterrupted power to the two vital 6 kW LV loads under a number of fault scenarios consisting of the failures of one up to four of the 3 kW DC/DC converters. Tables I depict a set of actions that the controller has to perform when one or more power electronic converters fail. The possible configurations, identified as 16 states as shown in Table I to IV, are dependent on the state of charge of the two batteries when the fault occurs. Table I shows the required actions under normal conditions. Tables II, III and IV show the actions to be initiated in case of failures of one, two and three/ four power electronic converters respectively. Depending on the state of the batteries and fault scenarios, the controller will act on the power converters, batteries and the switches to modify the power paths configurations of the EPS to ensure uninterrupted power flow to the vital loads, as described in Tables I to IV. The next section shows how the system changes configuration after the failure of one to four of the 3kW power electronic converters in simulation

Table I

No - Failure		
SOC	Battery 1: SOC = 90%	Battery 1: 50%<SOC<90%
Battery 2: SOC = 90%	State 1: - C4 open - No load shedding - Batteries 1, 2 disconnected	State 2: - C4 open - Load shedding - Battery 1 disconnected - Battery 2 charged until 90% SOC, go to state 1
Battery 2: 50%<SOC<90%	State 3: - C4 closed, - Load shedding - Battery 2 disconnected - Battery 1 charged until 90% SOC, go to state 1	State 4: - C4 closed - Load shedding - Battery 1 charged until 90% SOC (battery2 <90%), go to state 3 - Battery 2 charged until 90% SOC (battery 1 <90%), go to state 2

Table II

Failure of 1 DC/DC converters		
SOC	Battery 1: 20%<SOC<90%	Battery 1: SOC=20%
Battery 2: 20%<SOC<90%	State 5: - C4 closed - Batteries 1, 2 connected - If battery 1 SOC =20%, go to state 6 - If battery 2 SOC =20%, got to state 7 - If batteries 1/ 2 SOC = 20% , got to state 8	State 6: - C4 closed - Battery 2 connected - discharging faster - Battery 1 disconnected - If battery 2 SOC = 20% , got to state 8
Battery 2: SOC = 20%	State 7: - C4 closed, - Battery 1 connected - discharging faster - Battery 2 disconnected - If battery 1 SOC =20%, go to state 8	State 8: - C4 closed - Low priority loads disconnected – fast charge of the batteries - Battery 1 charged until 50% SOC (battery 2 - 50%<SOC<90% , go to state 5) - Battery 2 charged until 50% SOC (battery 1 - 50%<SOC<90%), go to state 5) - Batteries 1/ 2 SOC = 50% , go to state 5

Table III

Failure of 2 DC/DC converters		
SOC	Battery 1: 20%<SOC<90%	Battery 1: SOC=20%
Battery 2: 20%<SOC<90%	State 9: - C4 closed - Batteries 1, 2 connected - If battery 1 SOC =20%, go to state 11 - If battery 2 SOC =20%, got to state 10 - If batteries 1/ 2 SOC = 20% , got to state 12	State 10: - C4 closed, - Load shedding - Battery 2 disconnected - Battery 1 connected – discharging faster
Battery 2: SOC=20%	State 11: - C4 closed, - Load shedding - Battery 1 disconnected - Battery 2 connected – discharging faster	State 12: - C4 closed - Low priority loads disconnected - Batteries disconnected - High priority loads are supplied

Table IV

Failure of 3 DC/DC converters		
SOC	Battery 1: 20%<SOC<90%	Battery 1: SOC=20%
Battery 2: 20%<SOC<90%	State 13: - C4 closed - Batteries 1, 2 connected - If battery 1 SOC =20%, go to state 15 - If battery 2 SOC =20%, got to state 14 - If batteries 1/ 2 SOC = 20% , got to state 16	State 14: - C4 closed - Battery 2 connected - discharging faster - Battery 1 disconnected - If battery 2 SOC = 20% , got to state 16
Battery 2: SOC=20%	State 15: - C4 closed - Battery 1 connected - discharging faster - Battery 2 disconnected - If battery 2 SOC = 20% , got to state 16	State 16: - C6 closed - Load shedding - Batteries discharged - Low voltage buses disconnected and converters disconnected

V. SIMULATIONS AND RESULTS

This section applies the control strategy outlined in section IIIB to the EPS depicted in Fig. 4 by using the FSM that has been explained in section III. The simulations are performed in Simulink environment.

(a) Normal condition of operation

During normal condition, the state of charge of the batteries are maintained at 90%, as described in the state space table I and the state flow diagram in Fig. 5.

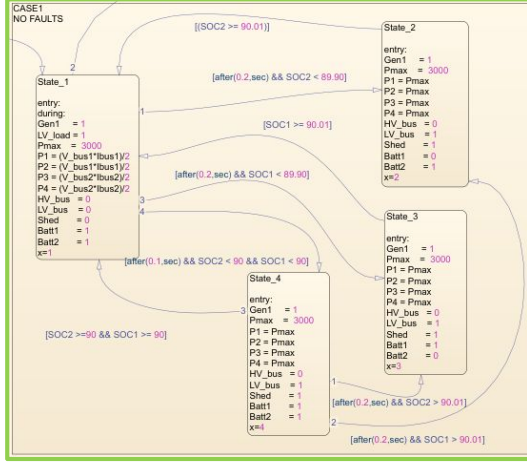


Fig. 5. No-fault scenario: State space diagram

The Fig. 5 shows the source code with the configuration of the states 1 to 4. Each state is defined inside the blocks in Fig. 5 while the arrows define the conditions to transition from one state to another. So, each state refers to a different configuration of the system. The main parameters used in the state diagram are defined next. Of note is that when the value assigned to the contactor is “1”, it is open and when the value is “0”, it is closed. LV_{load} represents the contactor used to connect ($LV_{load} = 1$) or disconnect ($LV_{load} = 0$) the non-essential load on the low voltage side. P_{max} represents the maximum power that can be transferred through one power electronic converter. $Batt_1$ and $Batt_2$ represent the commands used to connect or disconnect the batteries 1 and 2 respectively. P_1, P_2, P_3, P_4 represent the power that are transferred through the power electronic converter PEC 1, 2, 3 and 4 respectively, and are calculated based on the bus voltage V_{Bus} and the bus current I_{Bus} of the low voltage side. The contactor that connects the two HV buses is called HV_{bus} and acts on contactor C3 in Fig. 4. The contactor that connects the two LV buses is called LV_{bus} and acts on contactor C3 in Fig. 4. The variable $Shed$ is used to shed the power of the low voltage load, while the variable x is used to verify the state in which the system is working. Figs. 6 to 8 depict the simulation results under the no-fault scenario. From Fig. 6, it can be seen that the SOC of battery 1 (SOC1) and battery 2 (SOC2) are below 90% at the beginning of the simulation to $t=260s$; the system is in state 4. Between 260s and 317s, the SOC1 is 90% while SOC2 is below 90%; the system is in state 3. When the system is in states 4 and 3, the controller sheds the low priority loads, which consist of 1.5 kW on LV bus2, as is depicted in Fig. 8, and another 1.5 kW on LV bus1. The power thus made available from load shedding is used to

charge the batteries. The system transitions to state 1 after time $t=317s$ when the batteries are charged to 90%. The voltage on the buses is kept constant at 28 V in all states, as shown in Fig. 8.

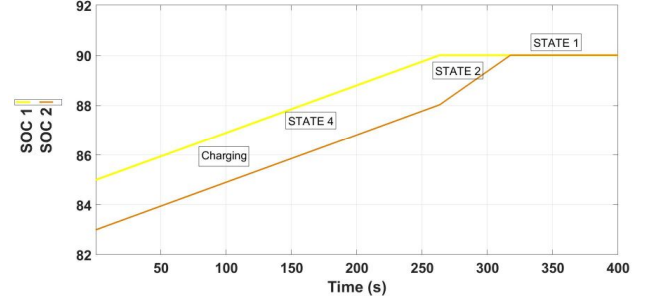


Fig. 6. No-fault scenario: states of charge of battery 1 and battery 2

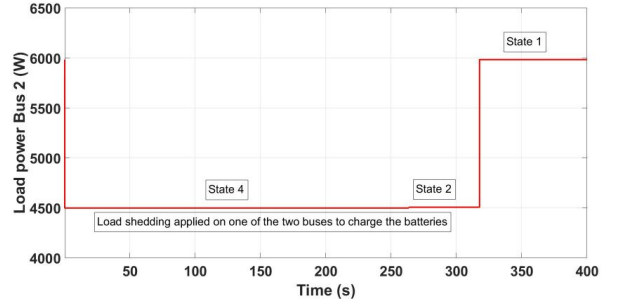


Fig. 7. No-fault scenario: Load shedding of 1.5 kW from LV bus 2 from $t=0s$ to $t=317s$ (and 1.5 kW from LV bus 1 which is not shown in Fig. 7)

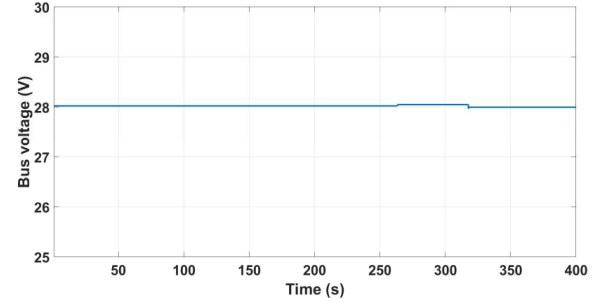


Fig. 8. No-fault scenario: Voltage maintained at 28 V on LV bus 2

(b) Failure of one power electronic converter

Fig. 9 shows the state transition diagram when the system is subject to the failure of one the power electronic converters (PEC 1). In this scenario, the system uses the remaining three converters to transfer maximum power to the loads. The 3KW power that can no longer be transferred through the faulty PEC1, is now supplied from the batteries. The batteries are used to supply all the LV loads until the SOC is below the minimum value of 20%. When the SOC is 20%, shedding is applied to the non-essential LV loads, and the surplus power thus available is used to recharge the batteries up to 50% as detailed in Table II.

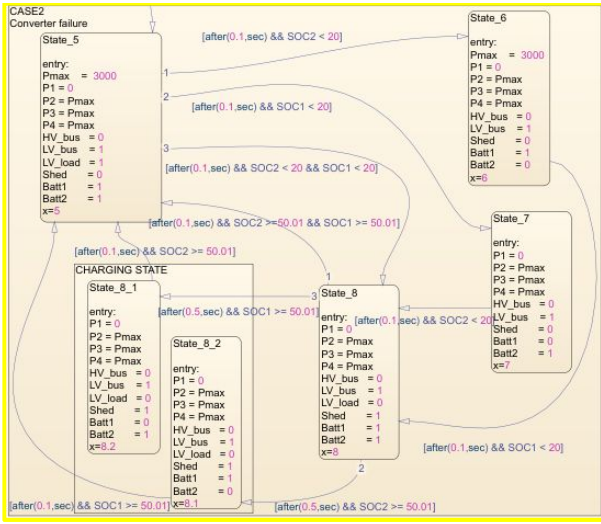


Fig. 9. State space diagram under failure of one power electronic converter

The Fig. 10 to 13 show the behaviour of the system after the fault in PEC1. After the failure of one converter which is shown in Fig. 10, the system starts using the batteries in order to supply the low voltage loads; the system thus transitions to state 5 as shown in Fig. 11. After the battery 1 is discharged, the controller disconnects it, and the system moves to state 7 where only the battery 2 is used, as depicted in Fig. 11. The system drains current from the batteries until the SOC's reach 20%. For 3480 s, the batteries are used to supply the low voltage loads, including the vital loads. Once the SOC's reach the minimum of 20%, the controller moves the system to state 8, as shown in Fig.11, disconnects the non-essential loads and start to charge the battery until SOC of the batteries are 50%. It is to be noted that the sub-states 8.1 and 8.2 are used to charge one battery at a time. Once the system charges the batteries up to 50%, the non-essential loads can be supplied again from the batteries as shown in Fig. 13 from time (t=5200s). Fig. 13 shows the plot of the load power on the bus 1 and bus 2. The total power on bus 1 is 4.5 kW which consists of only the vital loads. The total power on bus 2 is 1.5 kW which also consists the vital loads on bus1. Note that the vital loads are always supplied during the operation. The bus voltage is maintained nearly constant at 28 V, as the system states change, as can be seen in Fig. 13.

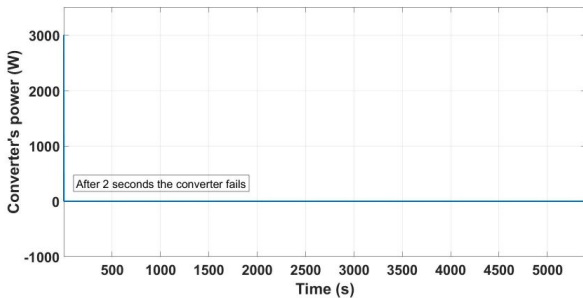


Fig. 10. Failure of one PEC: Power of PEC1 drops from 3kW to 0kW

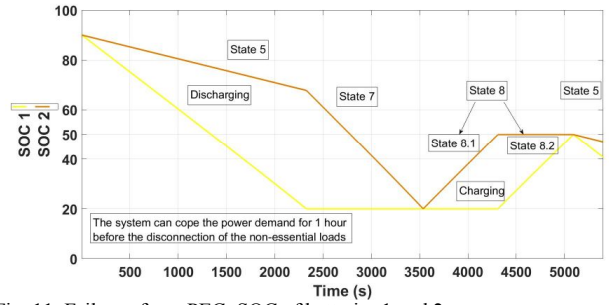


Fig. 11. Failure of one PEC: SOC of batteries 1 and 2

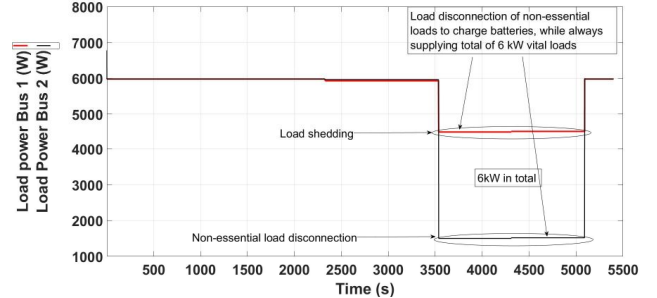


Fig. 12. Failure of one PEC: Load shedding of 1.5 kW on bus 1 and 4.5 kW on bus 2, with uninterrupted power to the vital load of 4.5 kW on bus1 and 1.5 kW from t= 3500s to 5200s

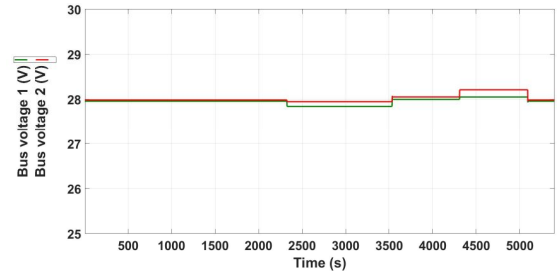


Fig. 13. Failure of one PEC: Voltage on 28 V buses

(c) Failure of two power electronic converters

The states of the system when two 3 kW power electronic converters fail are shown in Figure 14. The behavior of the system is detailed in the table III.

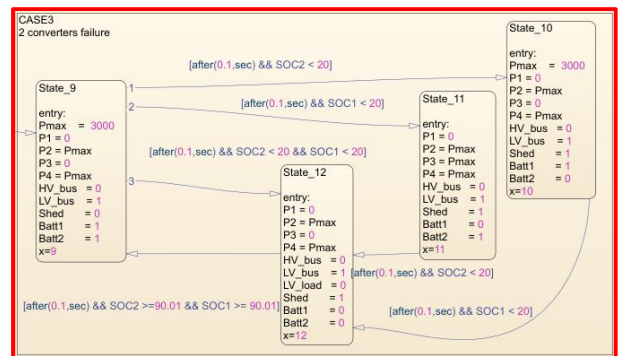


Fig. 14. Failure of two to four PEC: state space diagram

In the event of the failure of the two converters, the system transfers power to the low voltage buses through the remaining two healthy converters, and uses the batteries to provide the

surplus power required to the low voltage loads; the system is in state 9. The behavior of the system under this critical failure of the two PEC is shown in Figs. 15 – 17. The SOC of both batteries is 90% when the fault occurs; the system is in state 9. The contactor C4 is closed. Both batteries supply the non-essential loads, which can no longer be supplied through the two faulty PEC. When the SOC of the batteries reach 20% at time $t=1680s$ (28 mins), the batteries are not able to cope with the power demand as the SOC drops to 20%. So the controller disconnects the non-essential loads. As can be seen in the Fig. 16, once the SOC's are at 20%, the system is in state 12; the system disconnects the non-essential loads (1.5 kW on bus1 and 4.5 kW on bus2) and the two converters are used to supply the vital loads on the low voltage side (total of 6 kW). The voltage is kept constant at 28 V during the transidtions between states as hshown in Fig. 17.

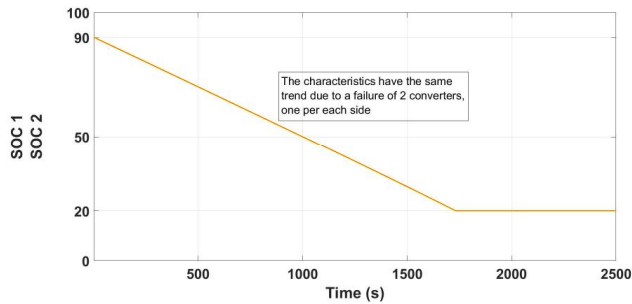


Fig. 15. Failure of two PECs scenario: SOC of batteries 1 and 2

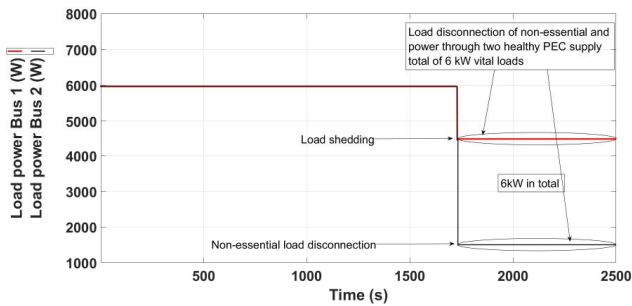


Fig. 16. Failure of two PECs: After 28 minutes the system disconnects the non-essential load of 1.5 kW on bus 1 and 4.5 kW loads on bus 2. All power through healthy PECs supply the total vital loads of 6 kW.

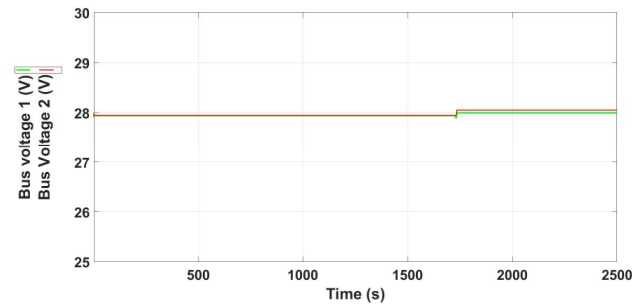


Fig. 17. Failure of two PECs: Voltage of the 28 V buses during all the operations

(d) Failure of three to four power electronic converters

Fig. 18 shows the states of the system in the event of the failure of three converters. The system states during the fault scenario is detailed in table IV.

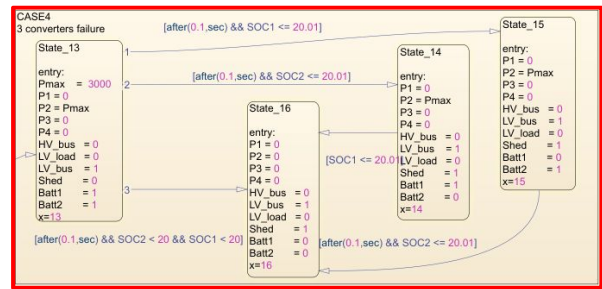


Fig. 18. Failure of three to four PEC: state space diagram

With the failure of a third converter, the controller uses the maximum power from the last healthy converter and the batteries to feed the low voltage high priority loads. The contactor C4 is closed. Shedding is applied to all the non-essential loads. As shown in Fig. 19, the total vital loads on LV side can be supplied for 28 minutes before the SOC of the batteries drop to 20%; after this point, the healthy 3kW PEC is used to supply only the 1.5 kW vital load. It is to be noted that if all four PECs fail, the batteries can supply the vital loads until their SOC's drop to 20%, after which point, neither the 1.5 kW nor the 4.5 kW vital loads can be supplied as shown in Fig. 20. In actual systems, the fault scenarios of three or four PECs failing is less likely to happen. If such extreme fault scenarios are to be accounted for, other emergency actions can be included in the design.

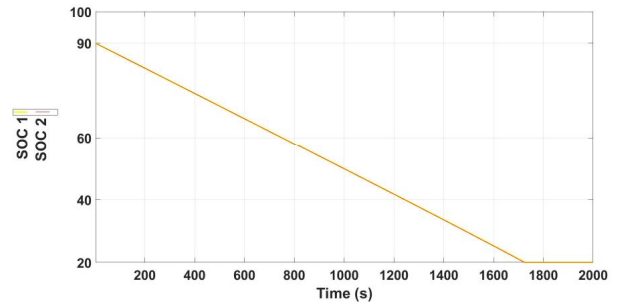


Fig. 19. Failure of three PECs: SOC's of batteries reach minimum of 20% after 28 minutes and cannot supply vital loads

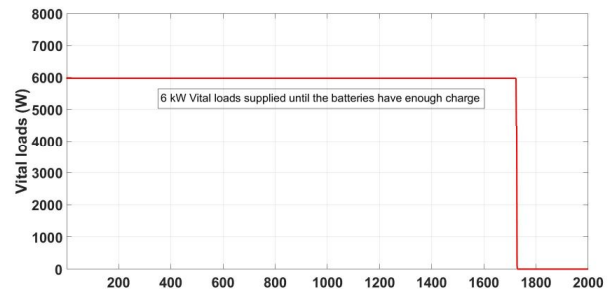


Fig. 20. Failure of fourth PECs: Power on 28V bus 1 and bus 2, after 28 minutes all the loads on low voltage side are disconnected

CONCLUSION

In this paper, the capability of a smart controller for the representative EPS of the future aircraft has been demonstrated. The strategy for the smart controller has been devised with the aim to provide uninterrupted power to low voltage high priority loads using FSM method. The control strategy has been implemented in Simulink and verified by considering faults scenarios involving the failure of one to four HV/LV DC/DC power electronic converters. The simulation results show that the controller activates the correct states such that the vital loads are always supplied for faults in up to two converters. For the unlikely event of three or four of power converters failing, the vital loads are supplied for a limited amount of time. Supplementary emergency actions can be taken into account if required by the design. This paper has shown how a smart controller can be designed to maintain the safe operation of an MEA electrical power system. As the electrical network of the future aircraft becomes more and more complex, the importance of having a smart controller is fundamental to enable fast and automatic decisions to be taken to protect the vital operations onboard.

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