Close Loop Control of Generator Control Unit for High Power Generator

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Abstract: *Aircraft electrical systems use a three-phase, 400 Hz, AC Bus supplied by engine driven generators. In an effort to simplify and improve the production of AC power for aircraft and to eliminate the need for hydro mechanical constant-speed drive (CSD), a number of systems have been devised for producing 400 Hz three- phase electric power using electronic circuitry .One of these systems is a DC-Link converter, which has a variable input frequency but a constant output frequency. This offer available alternative to the CSD as means of providing a constant frequency power supply from an aircraft generator. The ease of replacement and repair, the reduction in servicing needs, and the ability to locate the components of the electrical systems through the aircraft all combine to bring about a considerable reduction in the maintenance time required.*

Keywords - Generator, Rectifier, Inverter, Variable speed constant, Frequency, current, Microcontroller, Constant speed drive.

1. INTRODUCTION

Aircraft electrical systems use a three-phase, 400 Hz, AC Bus supplied by engine driven generators. In an effort to simplify and improve the production of AC power for aircraft and to eliminate the need for hydro mechanical constant-speed drive (CSD), a number of systems have been devised for producing 400 Hz three-phase electric power using electronic circuitry .One of these systems is a DC-Link converter, which has a variable input frequency but a constant output frequency. This offer a viable alternative to the CSD as means of providing a constant frequency power supply from an aircraft generator [1]. The ease of replacement and repair, the reduction in servicing needs, and the ability to locate the components of the electrical systems through the aircraft all combine to bring about a considerable reduction in the maintenance time required [5].

1.1 Project Outline

This project discusses aircraft generating systems, variable speed constant frequency systems (VSCF) .The operation and design of a three-phase PWM inverter and its associated control circuitry to produce 115VAC,200VL-L,400HZAC is described in detail by using TMS320F28377 PID control card.

2. LITERATURE SURVEY

- V.V. Vadher I.R. Smith S. Williams [2]**. "Mathematical Modeling of a VSCF Aircraft Generating System"** (IEEE INTERNET OF THINGS IEEE Transactions on Aerospace and Electronic Systems (Journal, Vol 6, No.4, AUGUST 2019). DC-link converters having a variable input frequency but a constant output frequency now provide a viable alternative to the constant-speed mechanical drive as a means of providing a constant frequency power supply from an aircraft generator. The ease of replacement and repair, the reduction in servicing needs, and the ability to locate the components of the electrical system throughout the aircraft all combine to bring about a considerable reduction in the maintenance time which is required typical results are presented for the overall system.

- Haibin Zhang Jianpeng Li, Bo Wen, Yijie Xun, and Jiajia Liu [3]**, "PWM- Based Optimal Model Predictive Control for Variable Speed Generating Units." (**IEEE Transactions on Industry Applications (Volume: 56, Issue: 1, Jan.-Feb. 2020). In this paper, we first overviewed the configuration is commonly encountered in gearless wind energy conversion systems as well as in variable speed generating units. The proposed control strategy uses an optimal voltage vector based modulated model predictive control (MPC) to achieve direct power control. The studied scheme combines the advantages of finite control set MPC and control techniques that use pulse width modulator **.**At each sampling instant, all the switching states are evaluated and the two adjacent states that give minimum error in the controlled variables are selected. The duty cycle of each of these vectors is computed through linear combination and appropriately limited for over modulation. The control strategy has been developed on a field-programmable gate array control platform and experimental results at steady state are shown, with the aim to demonstrate the computational feasibility of the control strategy.
- Sriharsha Venuturumilli , Frederick Berg , Lucien Prisse, Min Zhang, and Weijia Yuan [8].**"DC Line to Line Short-Circuit Fault Management in a Turbo-Electric Aircraft Propulsion System Using Superconducting)"**. (IEEE Transactions on Applied Superconductivity (Volume: 29, Issue: 5, Aug. 2019). In this paper it discussed about the Electric aircraft which has already become a reality, with demonstration flights at power ratings of less than 1 MVA. Conventional machines and distribution technologies suffer from poor power densities when scaling to large power demands, leading to significant challenges in applying this technology from small (<;10-seater) to large (>100-seater) planes. Superconducting devices could be an enabler for electric aviation due to their great potential for high efficiency and low weight. However, while the development of the superconducting components presents a significant challenge, the safe and effective combination of such components into a propulsion system also requires a significant area of research.
- Hua Xu, Jiadan We, Zhuoran Zhang [14] **"An Integrated Method for Three-phase AC Excitation and High-frequency Voltage Signal Injection for Sensor less Starting of Aircraft Starter/Generator."** (IEEE Transactions on Industrial Electronics (Volume: 66, Issue: 7, July 2019) This paper deals with an integrated method of three-phase ac excitation and high-frequency voltage signal injection (HFVSI) for sensor less controlled starting of brushless synchronous machines (BSM) used as starter/generator in variable frequency ac power systems of civil aircraft. Fixed 400 Hz of the three-phase ac power is adopted both for the ac excitation and HFVSI in the initial starting process to eliminate the bulky rotor position sensor for BSM. The resulting 6th sequence harmonic voltage determined by the rotating rectifier is utilized as the HFVSI into the field-winding of main generator without any extra high-frequency signal injection. The rotor position is estimated by the high-frequency response signals extracted from the armature windings of main generator. The effectiveness of the ac excitation and feasibility of rotor position estimation for sensorless starting control of BSM are validated by the simulation and experimental results.
- Hendrik Schefer, Leon Fauth, Tobias H. Kopp, Regine Mallwitz, Jens Friebe, and Michael Kurrat [12] **"Discussion on Electric Power Supply Systems for All Electric Aircraft"** IEEE Access (Volume: 8) 06 May 2020. The electric power supply system is one of the most important research areas within sustainable and energy-efficient aviation for more- and especially all electric aircraft. This paper discusses the history in electrification, current trends with a broad overview of research activities, state of the art of electrification and an initial proposal for a short-range aircraft. Research aspects and questions are discussed, including voltage levels, semiconductor technology, topologies and reliability.
- Sandro Gunter Giampaolo Buticchi, Senior Member, Giovanni De Carne, Chunyang Gu, Member, Marco Liserre, He Zhang,Chris Gerada.[13] **"Load Control for the DC Electrical**

Power Distribution System of the More Electric Aircraft”. (IEEE Access (Volume: 7) 07 June 2019). In this paper it deals with electric aircraft increasing the amount and the power of the electrical subsystems on the next generation of aircraft .The electric power is generated by means of electrical generators connected to the jet turbine shaft. In order to satisfy the peak power demand and overload conditions, the generators are oversized, increasing weight and total cost of operation is discussed. Modifying the dc voltage of the distribution, the load can be controlled. In order to achieve this objective, a precise on-line identification algorithm is proposed.

- Flyur R. Ismagilov, Mikhail A. Kiselev, Viacheslav E. Vavilov [11] **“Electrical and Electronic Technologies in More-Electric Aircraft”** (IEEE Transactions on Aerospace and Electronic Systems (Volume: 55, Issue: 6, Dec. 2019). In this paper, the electrical and electronic technologies investigated in more-electric aircraft (MEA). In order to change the current situation of low power efficiency, serious pollution, and high operating cost in conventional aircraft, the concept of MEA is proposed. By converting some hydraulic, mechanical, and pneumatic power sources into electrical ones, the overall power efficiency is greatly increased, and more flexible power regulation is achieved. Electrical machines and power electronics devices. The design and control methods for electrical machines and various topologies and control strategies for power electronic converters researched.

3. EXISTING SYSTEM

A constant speed drive (CSD) is a type of transmission that takes an input shaft rotating at a wide range of speeds, delivering this power to an output shaft that rotates at a constant speed, despite the varying input. They are used to drive mechanisms, typically electrical generators that require a constant input speed.

The term is most commonly applied to hydraulic transmissions found on the accessory drives of gas turbine engines, such as aircraft jet engines. On modern aircraft, the CSD is often combined with a generator in to a single unit known as an integrated drive generator (IDG) CSDs are mainly used on airliner and military aircraft jet engines to drive the alternating current(AC) electrical generator.

In order to produce the proper voltage at a constant AC frequency, usually three-phase 115 VACat400 Hz, an alternator needs to spin at a constant specific speed (typically 6000 RPM for air-cooled generators).[1]Since the jet engine gearbox speed varies from idle to full power, this creates the need for a constant speed drive (CSD). The CSD takes the variable speed output of the accessory drive gearbox and hydro mechanically produces a constant output RPM.

Figure 1. Integrated Drive Generator

The complete unit is called an integrated-drive generator (IDG). The principle of operation for all CSDs is essentially the same, but these integrated drive generator (IDGs) systems have the advantage of a lower weight as compared to discrete CSD systems.

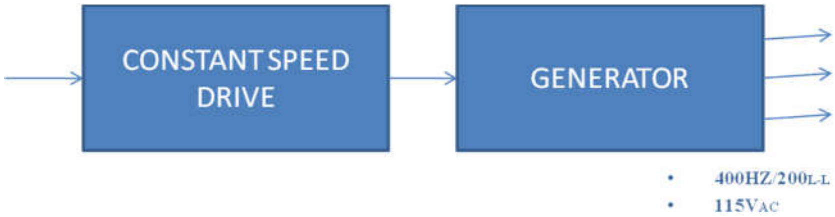

Figure 2.Block Diagram of CSD

3.1 Construction and Working Principle

The Constant-speed drive (CSD) is employed with each generator on each engine. The CSD has the ability to convert a variable engine speed to a constant rpm.20. The complete CSD system consists of an axial-gear differential (AGD) whose output speed relative to input speed is controlled by a flyweight-type governor that controls a variable-delivery hydraulic pump. The pump supplies hydraulic pressure to a hydraulic motor which varies the ratio of input rpm to output rpm for the AGD in order to maintain an AC frequency of 400 HZ. The operation of the CSD may be understood by tracing the mechanical actions. A constant speed unit coupled to a generator, based on the Sundstrand design which is in use in several current types of turbojet-powered aircraft [4]. CSD employs a hydro mechanical variable-ratio drive which in its basic form, consists of a variable- displacement swash plate type of hydraulic pump and constant displacement swash plate type of motor. The oil for system operation is supplied by charge pumps and governor systems fed from a reservoir which is pressurized by air tapped from the low-pressure compressor of the engine[6]. Power from the engine is transmitted through an input shaft and gears, to a hydraulic cylinder block common to both pump and motor, and by the action of the internal hydraulic system, is finally transmitted to the motor and output gears and shaft coupled to the generator .When the engine output is exactly equal to the required generator speed, the oil pressure and flow within the hydraulic system are such that the motor is hydraulically locked to the cylinder block and they rotate together; thus, the whole transmission system acts as a fixed coupling. If however, there is a change in engine and input shaft speed, the governor system senses this and applies a greater or smaller pressure to the pump to vary the angle of its swash-plate. For example, if engine output is slower than the required generator speed, called an‟ over drive‟ condition, the pressure increases; conversely, in a ‟under drive‟ condition when engine output is faster, the pressure decreases.

3.2 DRAWBACKS

In order to provide constant speed generator operation it is common practice to use constant speed drive (CSD) to couple the output of the engine to the input of the generator. This system is very expensive, complex and must be located close to the engine. However recently developments in both power electronics and microprocessor technology have led to the electrical variable speed constant frequency (VSCF) systems becoming a viable alternative to the CSD.

4. PROPOSED SYSTEM

All modem aircraft and spacecraft are very largely dependent upon electrical power for communications, navigation and control. Typical electrical loads in aircraft include identification lights, landing lights, instrument lights, heaters, retractable landing gear, wing flaps, engine cowl flaps, radio, and navigation equipment and so on. The main electrical supply for the aircraft is provided by generators coupled to the engine, and power is also supplied by batteries which act as a back-up system .Aircraft electric power requirements have expanded with the advancement in technology of modem aircraft systems. Flight control and other computers demand the delivery of reliable, uninterruptible power. The introduction of low bleed engines to increase reliability, maintainability, and damage tolerance capabilities has resulted in reduced pneumatic power availability.

This, along with the replacement of hydraulic systems and accessories with electric equipment, has led to the requirement for larger electric generating systems

4.1 Working DC-Link Variable Speed Constant Frequency

With the availability of high voltage, high-power transistors, DC-Link converters having a variable input frequency but a constant output frequency now provide a viable alternative to the constant-speed mechanical drive as a means of providing a constant frequency power supply from an aircraft generator. The ease of replacement and repair, the reduction in servicing needs, and the ability to locate the components of the electrical system throughout the air craft all combine to bring about a considerablereductioninthemaintenancetimewhichisrequired.Thegeneratorisdriven directly by the engine, so its speed and output frequency will vary as engine speed varies The variable three-phase power is fed to the full-wave diode rectifier, where it is converted to direct current and filtered. This direct current is fed to the conversion circuitry, to produce three-phase 400 HZ alternating current The DC-link system may be physically separated or integrated into one package .Variable Speed Constant Frequency (VSCF) Aircraft Electrical Power. A high frequency, multi-phase, brushless generator supplies power to a frequency converter which conditions the variable frequency generator output into precision 3-phase, 115/200V, 400 Hz aircraft power.

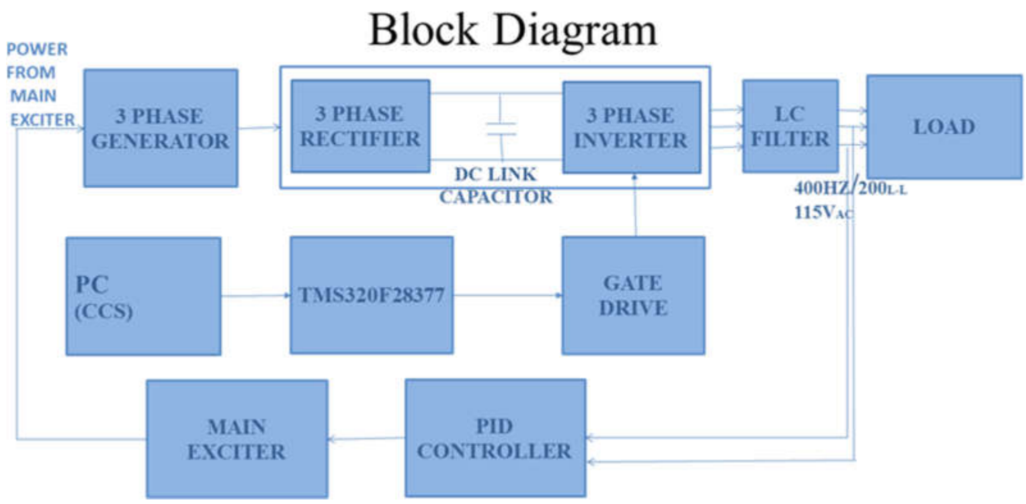

Figure 3.Block diagram of proposed system

4.2 Microcontroller Tms320f28377 and Gate Drive Block Diagram

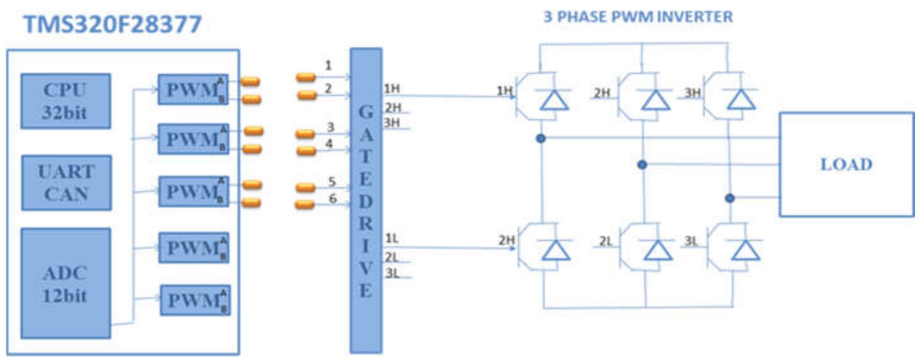

Figure 4.Microcontroller TMS320F28377

4.3 Software

4.3.1 Code Composer Studio

Code Composer Studio software comprises suite of tools used to develop and debug embedded applications. The software includes an optimizing C/C++ Compiler, source code editor, project build environment, debugger, profiler and many other features .By using this software the coding is done to microcontroller (TMS320F28377).

Features

- TMS320C28x32-bitCPU
- 200 MHz
- IEEE754single-precisionFloating-PointUnit(FPU)
- Trigonometric Math Unit(TMU)
- Viterbi/Complex Math Unit(VCU-II)
- Programmable Control Law Accelerator(CLA)
- 200 MHz
- IEEE754single-precisionfloating-pointinstructions
- Executes code independently of main CPU
- On-chip memory
- 512KB(256KW)or1MB(512KW) off lash (ECC-protected)
- 132KB (66KW) or 164KB (82KW) of RAM (ECC-protected or parity-protected)

VREF+ and VREF- are reference voltages and are used to limit the analogue voltage range. Any input voltage beyond these reference voltages will produce a saturated digital number. All voltages must remain within the limits of their maximum ratings, as specified in the data sheet

4.3.2 Gate Drive

A gate driver is a power amplifier that accepts a low-power input from a controllerICandproducesahigh-currentdriveinputforthegateofahigh-power transistor such as an IGBT. It is used when a PWM controller cannot provide the output current required to drive the gate capacitance of the associated power

4.3.3 Connection from Control Board to Gate Drive

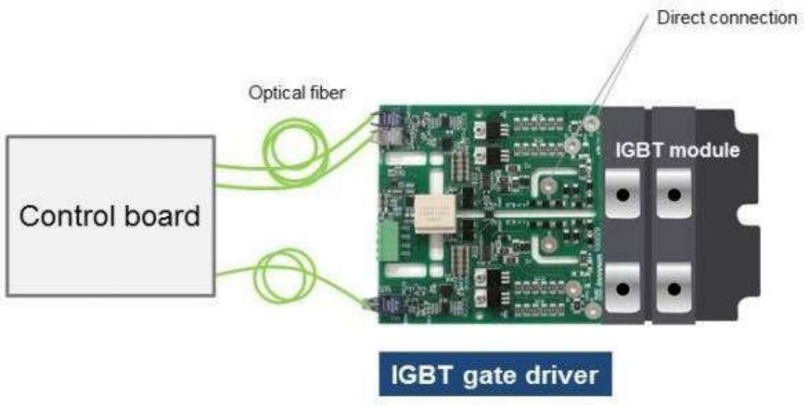

Figure 5.Connection from Control Card

4.4 Gate Drive Working

1. The driver must be able to provide the necessary average output gate current and this must be higher than the calculated value for the selected IGBT module.
2. The maximum peak gate current of the driver must be more than the calculated value for the selected IGBT module.

4.4.1 Calculation by using Unity Power Factor Output Requirement at the DC Link Converter

PAC	= 75 KVA
V	=115VPh/220VL-L
3V0I0	= 75000VA
Io	=217.4A

Power Calculator at DC Link Rectifier (AC -DC)

PAC	= PDC /95% (assume 95% efficiency)
PAC	= 87.72KVA
3VPHIPH	= 87.72KVA
VPH	= 115V
VL-L	= 268.5V

Power Calculation for DC Link Inverter (DC TO AC)

PDC link	= 83.3 KVA(assume 90% of efficiency)

By sine PWM

V L-L	= 0.6124 x MA x VDC
MA	= 0.9
VDC	= 363V
PDC link	= VDCIDC
IDC	= 229.5A
MA	= MODULATING INDEX

5. CONCLUSION

The detailed execution of this project is followed. The full advantage of VSCF in any application of automation area can be taken for the development of the application of high reliability, variable speed constant frequency (VSCF) aircraft electric power generating systems. A high frequency, multi-phase, brushless generator supplies power to a frequency converter which conditions the variable frequency generator output into precision 3-phase, 115/200V, 400 Hz aircraft power .This is an ongoing project and the F18 Aircraft is currently in testing AV8B and AF5G Aircraft are under development, but in future it can be expanded in many other Aircraft.

6. FUTURE SCOPE

In future, this project can be expanded with some more advance feature like controlling the Aircraft with constant speed in auto pilot mode.

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