Sudan University of Sciences & Technology

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The Ground Power Unit To supply aircrafts

وحدة الطاقة الأرضية لامداد الطائرات

A project Submitted In Partial Fulfillment for the Requirement of the Degree of B.Sc. (Honor) in Electrical Engineering

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الاية

قال تعالى :

" اللَّهُ لَا إِلَهَ إِلَّا هُوَ الْحَيُّ الْقَيُّومُ لَا تَأْخُذُهُ سِنَةٌ وَلَا نَوْمٌ لَّهُ مَا فِي السَّمَاوَاتِ وَمَا فِي الْأَرْضِ مَن ذَا الَّذِي يَشْفَعُ عِندَهُ إِلَّا بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلَا يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِ إِلَّا بِمَا شَاءَ وَسِعَ كُرْسِيُّهُ السَّمَاوَاتِ وَالْأَرْضَ وَلَا يَئُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ ﴿255﴾" سورة البقرة

صدق الله العظيم

Deduction

To my mother dear, thank you for the patience of an endless.

To the big heart my dear father.

To those who have shown me what is the most beautiful, brothers and sisters.

To the people who paved our way of science and knowledge, All our teachers.

To the most beautiful moments with my friends.

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Abstract

Because the maintenance of the ground power unit to supply aircrafts is not widely available, it was necessary to be identified in detail and submit it in a simplified manner, to understand the work of this unit.

The project is Practical study of GPU included Field visits to military airport base, khartoum international airport and Darrag engineering workshop.

It was also practical design of ground power unit has been done. while giving the same output in terms of voltage and frequency.

المستخلص

نظرا لان عملية الصيانة لهذه لوحدة الطاقة الأرضية لامداد الطائرات غير متوفرة بشكل واسع كان لابد من التعرف عليها بصورة تفصيلية وتقديم ذلك بطريقة مبسطة تمكن من فهم عمل هذه الوحدة.

المشروع عبارة دراسة عملية لوحدة الطاقة الأرضية شملت زيارات ميدانية للقاعدة العسكرية الجوية ومطار الخرطوم الدولي وكذلك ورشة دراج الهندسية.

تم عمل نموذج مبسط لوحدة الطاقة الأرضية له خرج مشابه لخرج الوحدات القياسية من ناحية الجهد والتردد.

TABEL OF CONTETNS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Y	Yes
N	No
V	Volt
A	Ampere
CB	Circuit breaker
P.U	Protection unit
PB	Pushbutton
Hz	Hertz
DC	Direct current
AC	Alternating current
IP	Ingress protection
GPU	Ground power unit
APU	Alternator protection unit
A.V.R	Automatic voltage regulator
TRU	Transformer rectifier unit
ALT	Alternator
ASSY	Assembly
AUX	Auxiliary
LED	Light emitting diode
P.C.B	Printed circuit board
POT	Potentiometer
SOL	Solenoid
rpm	Revolutions per minute

CHAPTER ONE

INTRODUCTION

1.1 General Concept

Some wonder what kind of power an aircraft uses when parked at the airport stand. Normally the aircraft generates its own power, but when parked with the engines switched off power provided by the airport would be connected to the plane. This connected power is typically 115 V at 400 Hz and is called ground power. The amount of kVA required is dependent on the aircraft type and size. we use GPU for cargo**,** check, maintenance and repair purposes, also to Reduce consuming the main engine of aircraft thus the main engine will be long lasting, Reduces, noise and the danger due to aircraft fans and the high cost of aircraft fuel compared with GPU fuel.

1.2 Problem Statement

Because the maintenance of this unit is not widely available, it was necessary to be identified in detail and submit it in a simplified manner, to understand the work of this unit.

1.3 Objectives

A study of the ground power unit and troubleshooting that may occur and its maintenance.

1.4 Methodology

Field work at military airport base, khartoum international airport and Darrag engineering workshop and Practical study of GPU and Design small model of ground power unit.

1.5 Project Layout

The project contains five chapter. Chapter one ’introduction’ contains general concept of GPU, project objectives, project methodology and project layout.

Chapter two ‘types of ground power units’ contains types of GPU and ground power unit model d690 components and operation. Chapter three ‘model of ground power unit’ contains GPU model components and operation. Chapter four ‘fault diagnosis of GPU model d690’ contains faults may be occurred in GPU and diagnosis of these faults and also matlab programe for the faults. Chapter five ‘conclusion and recommendation’ contains a project conclusion and recommendations and hired references.

CHAPTER TWO

THE GROUND POWER UNIT

2.1Types of Ground Power Units

There are two basic types of ground power unit.

2.1.1 Fixed ground power

Fixed ground power is the supply of suitable 400 Hz power using a permanently installed installation for use on parked aircraft. Conversion of the mains power to 400 Hz power is typically done either centralized or at the point of use by frequency converters. In a centralized system, large quantities of power are converted at a central location and then the 400 Hz power is distributed to the aircraft. In point of use, the mains power is taken close to the aircraft, and the frequency conversion carried at its point of use. Centralized power systems while cheaper to construct, do have several disadvantages. These include the balancing of the system, maintaining adequate voltage drops amongst others.

2.1.2 Mobile ground power

Where fixed ground power is not available, mobile power units can be deployed. These are typically towed or mounted on vehicles and deliver power by utilizing diesel generators [1].

.2.2 Electrical Characteristic

Aircraft have strict specifications for the quality of power: 115 V ±3 V, 400 Hz. The amount of kVA required is dependent on the aircraft type and size. During design processes, the amount of power required is calculated and suitable equipment installed. For point of use converters (see below), these are often standardized as 90 kVA units.

2.2.1 Technical Considerations

400 Hz power needs additional technical considerations above that for standard 50 or 60 Hz. Within any cable, the impedance presented by the

inductive reactance is proportional to frequency ($X = 2\pi fl$). For 400 Hz systems, the impedance will be around eight times larger than normal mains systems and consequently voltage drop becomes a major issue. in addition for normal four core cables, the distance between of each phase is not equal [due to the neutral conductor taking up space (in the image a3 is larger than a1 or a2)]. This creates an imbalance and consequently the inductance of each phase varies. This variation of inductance between phases, while not that important at mains frequency, become more pronounced at 400 Hz and can lead to imbalanced voltages. To reduce any imbalance in inductive reactance, often special symmetrical seven core cables are used - with interspersed phases wrapped evenly around a neutral conductor [1].

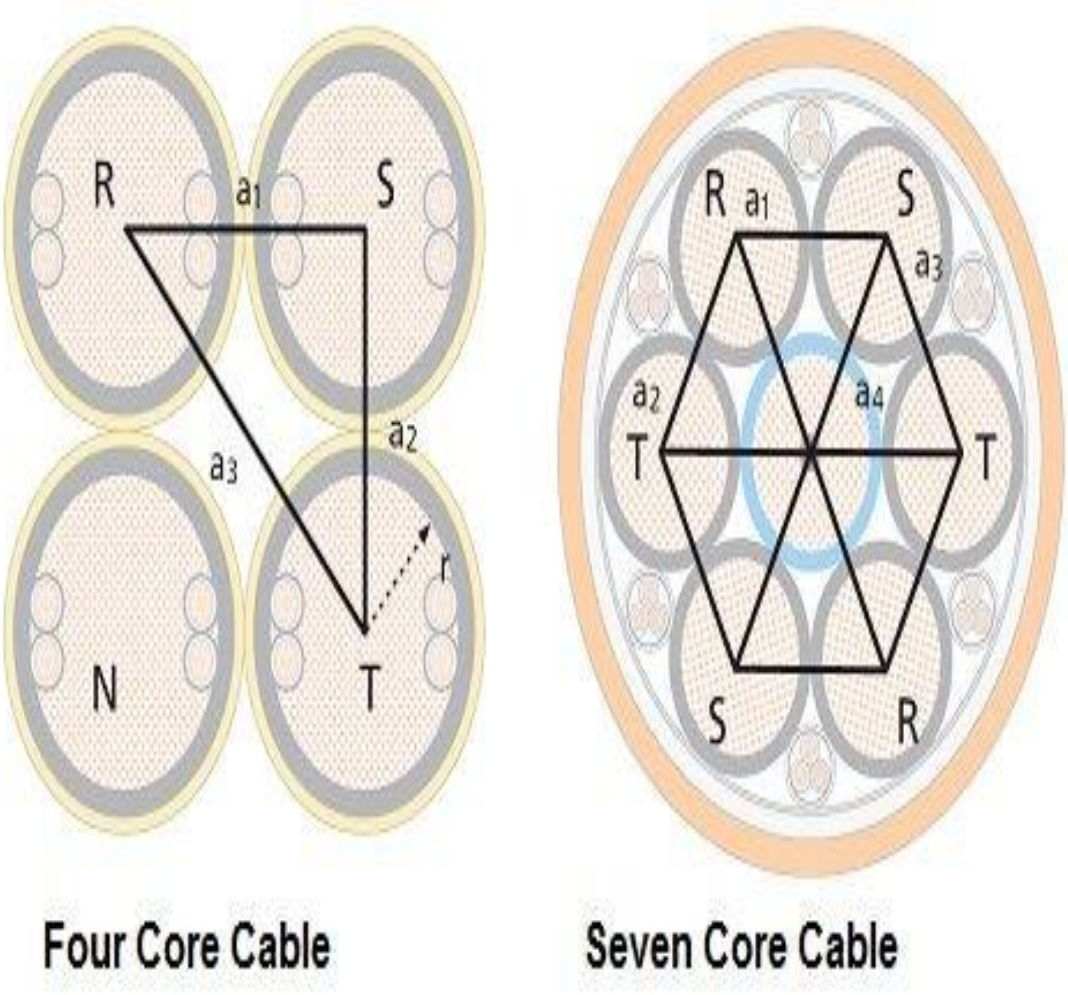

Figure 2.1: Unbalanced and balanced cables

2.2.2 Voltage drop

Maintaining 115 V at the aircraft plug in connector can be difficult, this is especially so where each phase is unbalanced. Several methods exist for ensuring the correct voltage level at the aircraft. Two methods which yield reliable results for point of use converters are: measurement wires embedded in the main cable measure the voltage at the aircraft. Each individual phase output of the inverter is then adjusted to give the correct voltage at the plane, and characteristics of the supply system and cable are determined by automatic measurements. The output of each inverter phase is then adjusted according to the measured current**.**

2.3 Frequency Converters

Commercial mains power at most airports operates on either 50 or 60 Hz. Frequency converters are required to change this to the 400 Hz required for aircraft operation. No break power transfer: most modern aircraft operate a no-break power transfer. this means that consumption is transferred from the air-crafts own power generation units to ground generated power without any interruption. Synchronization and switching over of the power supplies is carried out by equipment on board the aircraft.

Tip: aircraft synchronism equipment is not always the most accurate. Employing frequency converters which can detect aircraft synchronization problems and react accordingly is a good idea [2].

Figure 2.2: Two 90 kVA point of use frequency converters

2.4 Final Power Delivery

There are many ways for delivering 400 Hz power to the aircraft. Two common methods employed at larger airports are bridge mounted cable reel devices or apron buried pit systems. Bridge mounted devices are attached to the passenger embarkation/disembarkation bridges and electrically controlled to dispense the 400 Hz cable. After operations, the device will electrically rewind the cable back onto its cable reel. Pit systems typically contain the 400 Hz cable, which is accessed by lifting a lid on the pit. Additionally, some pop-up type pit systems are available, which simply the cable handling. In addition to cable handling, pits systems also need to be designed to take the mechanical load of aircraft driving over them. Being buried, they are also considered to be confined spaces [1].

Figure 2.3: Bridge Mounted Cable Coiler

2.4.1 Aircraft Connection

Connection to the aircraft itself is made using special plug in connectors. Depending on the size of the plane, the number of required connectors varies from one to four. Aircraft connectors are standardized and rated at IP67.Connectors are often integrated with push buttons and LEDs for operating frequency converters and power delivery systems. Typical specification ratings would be 200 V, 200 A continuous within a temperature range: -55°C to +125°C [3].

2.5 Comparison Between Different Types of Mobile GPU

Table 2.1 A comparison of four different types of mobile GPU

GPU Model	D 690	GA100D	GB3/2	G15Q
Dimensions L x W x H (mm)	3.65x1.755x1.69	1.8x0.9x1.2	1.26x0. 6x0. 82	3.99 x 2 x 1.945
Weight (kg)	2480	1100	170 (87 + 83)	4400
Engine	Overheat Low oil pressure Over speed protection Speed 2400 rpm	Over speed Turbo diesel Low oil pressure Air filter clogging-up Speed 2182 rpm	Overheat Low oil pressure Cooling type air Fuel Diesel and JET Fuel Speed 3429 rpm	Air cleaner Disposable dry type Governor Electronic Speed 1500 rpm
Data	140 KVA 0.8lag AC Voltage 115/200V 3Phase, 4Wires Frequency 400 HZ DC Voltage 28 Current 800 A	100KVA,0.8lag AC Voltage 115/200V 3Phase,4Wires Frequency 400 HZ DC Voltage 28.5 Current 600A	3KVA,0.8lag Ac Voltage 115/200V 3Phase,4Wires Frequency 400 HZ DC Voltage 28.5 Current 60A	180KVA,0.8lag Ac Voltage 200/115V 3Phase,4Wirs Frequency 400 HZ DC Voltage 24 Current 522A

CHAPTER THREE

THE D690 MODEL

3.1 Ground Power Unit Model D690 Components

The ground power unit model D690 its contains several components, the most important :

3.1.1 Engine

The Deutz BFo6M1013EC is a six-cylinder, turbocharged, water-cooled diesel engine. Itis with electrical starting, a speed control system and a battery charge alternator. Automatic shutdown devices protect the engine in the event of low oil pressure, high water temperature coolant or over speed.

3.1.2 Alternator

The alternator is a static armature brushless machine, wound to give an output of 200V line 400Hz, 3-phase, 4 wire, when running at 2400 rpm. the rotor drive end is directly coupled to the engine flywheel through a spring steel disc coupling. The stator is bolted to the flywheel housing. The non-drive end of the rotor is supported by a single spherical roller bearing. which is lubricated through a grease nipple fitted with an extension tube. Initially, the alternator is excited by the starter battery, which energizes the stator exciter field windings. This induces a current in the auxiliary windings on the rotor. This is rectified by the rotating diode assembly and fed to the stator field windings, and the alternator begins to produce an output. The alternator protection unit APU switches off the battery exciter supply when the excitation is self-sustaining. The excitation current is controlled by the automatic voltage regulator AVR. acentrifugal fan mounted on a carrier ring at the bearing end of the rotor cools the alternator. Airflow is through the End shield, over the alternator windings and out through the stator at the coupling end of the alternator [3].

3.1.3 Control panel

The control panel, including the output switch gear, is mounted on a hinged support at the front end of the units, protected by a hinged Perspex cover. The complete control panel and support can be lifted on a hinge to expose the 28V DC Transformer Rectifier Unit (TRU).

3.1.4 Transformer rectifier unit (optional)

The 28 Dc transformer rectifier unit assembly TRU bolted directly to the chassis floor beneath the hinged control panel support. The TRU operates from the output from the alternator. output switching contactor are located in the enclosure below the power rectifier and enclosure below the control panel. The control circuits, switches and indicator lamps are added to a section of the control panel facia. The output is regulated by adjusting the 400Hz AC input. If the 28v Dc supply is in use the 400Hz/200V AC supply is unavailable for external use and the diagram shown in appendix (B).

3.1.5 Current limit control (optional

With this device, the output current of the TRU will be limited to 1600A. A switch is fitted to allow the current limiting to be selected ON or OFF as required.

3.1.6 Trailer and canopy

The equipment is mounted on a four-wheel trailer within a weatherproof canopy,

with integral cable-stowage compartments on either side. The trailer is fitted with semi-elliptical leaf spring suspension, turntable steering and pneumatic types. The fuel tank is mounted transversely underneath the trailer between the wheels. the front wheel brakes are automatically actuated when the towbar is in either the lowered position or the raised 'stowed' position. The towbar has an overrun brake mechanism and cross-cable operated drum brakes fitted to the front wheels. the equipment is enclosed by a canopy that is in two sections that run on nylon wheels in tracks. The control panel (front) section

slides beneath the rear (engine) section to allow access to the electrical switchgear. The engine section slide forward for access to the engine. The sections are secured in their normally closed positions by anti-loose fasteners. the canopy sections are lined with acoustically absorbent material and a noise-reducing air deflector is fitted at the rear of the trailer [4].

3.2 Ground Power Unit Model D690 Operation

This model will be run in this following points:

3.2.1General

It is recommended that, before operating the equipment personnel thoroughly familiar with the location and function of all the control and indicators. if the unit is not in regular use, the engine should run for at least half an hour each week to lubricate the internal parts and reduce the risk of internal corrosion. it is also recommended that the engine be nun on full load for 10 minutes at intervals of 50 hours, in order to clear carbon deposits from the engine. warning - this equipment operates at potentially lethal voltage levels.

3.2.2 Parking and towing

The ground power unit must be positioned on firm, level ground The front wheel brakes will be automatically actuated with the towbar in either the lowered position or raised to the stowed position.

The overrun brake mechanism incorporates a reversing catch on the towbar that must be engaged when reversing the unit to prevent brake application. in preparing to tow the unit, the reversing catch must be released to allow the overrun brake to operate.

3.2.3 Pre-start checks

it is the first start of the day, parry out the daily maintenance checks on the engine, referring to the Deutz operation and Maintenance Manual. Then check the gauge on the fuel tank and replenish as necessary. caution- the fuel tank should never be allowed to run dry otherwise air will be drawn into the fuel system, affecting the running of the unit. the engine is new, or has been

standing idle for more than two months, prime the engine fuel system before starting. Refer to the engine manufacturers service manual for detailed information and method. after that Ensure that the manually operated circuit breaker, located under the canopy, behind the instrument panel, is in the ON position. The circuit breaker should remain in the ON position except when the equipment is laid up for any length of time, Finally turn the battery isolator switch (when fitted) to ON. This switch is located close to the batteries.

3.2.4 Engine starting-normal

Turn the IDLE service switch to the IDLE position, then insert the key into start switch and turn clockwise to 'R' position. The battery charge lamp will illuminate. turn the key further clockwise, against spring pressure, to the 'HS' position to energize the starter motor. When the engine 'fires' and begins to accelerate release the key switch, which will return to the 'R' position. note - if the engine fails to start within 10-20 seconds of first turning the start switch to the 'r' position, a low oil pressure fault warning will be initiated, if this occurs, turn the start keys witch to off, wait 2 minutes, then repeat the start attempt. Caution – do not crank the engine for more than 30 seconds. Waite 2 minites between unsuccessful start attempt. when the engine has started, check that the battery charge warning lamp has been extinguished.

3.2.5 Using the 200V AC output

caution-when using the 200VAC output supplies, do not exceed the maximum continuous rating of tour unit, the maximum continuous current through any one ac output cable must not exceed 260A. note - the AC output cannot be used simultaneously with a 28v DC output from the uncontrolled transformer rectifier unit.

3.2.6 Obtaining a 200V AC output

Start the engine as described, then check the BYPASS ON lamp This should normally be extinguished as the aircraft interlock system is preset to

INTERLOCK. If the aircraft being serviced does not have a 28V DC feedback supply through pole F of the output cable socket, then it will necessary to reset the system to BYPASS. to reset BYPASS first Shut own the engine then Release the fasteners which secure the engine/AC instrument panel open, locate the system switch on the inside of the panel and select BYPASS Close and refasten the panel, then restart the engine as previously described. after that operate the IDLE/SERVICE switch to SERVICE position. The engine speed will increase to the servicing speed of 2400 rpm, then Check that the AC digital meter read Channel 1-zero volt, and Press the excite switch and hold until the AC voltage rises between 113V and 117V. note if the AC output contactor open lamps are fitted, these will illuminate when the alternator is excited and remain illuminated until the corresponding output contactor closes. then Select the meter to channel 7-Frequency. The frequency should be between396 and 404 HZ, and Connect the output cable (s) to the aircraft, then Press the Output (no.1 /and or Output no.2, if fitted) pushbutton switch The power on lamp will light up to indicate that the output contactor(s) has/have closed to connect power to the output cable socket(s). The indicated voltage on load should be between 113 and 117V and the (Frequency between 395 and 405Hz.

3.2.7 Disconnecting The 200V AC Output

first Press the appropriate Output OFF pushbutton switch. THE POWER ON lamp will be extinguished to indicate that the output contactor has opened to disconnect power from the output cable socket, then disconnect the AC output cable from the aircraft. warning - do not pull the live socket from the aircraft plug.

3.2.8 Stopping the engine

Ensure that the power On lamp(s) is/are extinguished and disconnect the output cable from the aircraft, and select the IDLE/SERVICE switch to IDLE. Allow the engine to idle for 3-5 minutes then tum the start key switch to the

OFF position. aution-ensure that the engine idles for 3-5 minutes before stopping after load application. this allows lubricating oil and coolant to carry heat away from combustion chambers, bearings, shafts etc. this is particularly important for turbocharged engines. do not let the engine Idle for more than 10 minutes using the uncontrolled 28V DC output. the AC output cannot be used at the same time as the 28V DC uncontrolled output.

3.2.9 Obtaining a 28V DC output

first start the engine as described earlier and proceed to excite as if about to use 200V 400HZ output, except that 28VDC output cable is plugged into the aircraft. Press the 28V DC ON switch. The POWER ON lamp will illuminate to indicate that power has been connected to the aircraft, then select the DC meter to Channel 1. Check that the DC voltage is between 27 and 29. After that select the meter Channel 2 monitor the output current. caution do not exceed a continuous output of 800A note - the TRU may have the optional current limit facility this will automatically limit the maximum output current by reducing the ac alternator voltage. Current limit selection is by means of switch located inside the DC section of control panel. A potentiometer, also inside the control panel, allows adjustment of the maximum current level, although this is normally preset and labelled [2].

3.2.10 Disconnecting The 20V DC output

Press the 28V DC OFF switch. The POWER ON lamp will extinguish to indicate that power has been disconnected from the aircraft, then disconnect the 28V DC output cable from the aircraft. warning - do not pull a live socket from the aircraft plug. Finally shut down the engine as previously described.

3.2.11 Speed adjust control

The speed adjust potentiometer on the control panel provides fine control of engine speed. it is normally preset and looked but, if adjustment is necessary, it should be carried out with the alternator excited and unit running without load. Frist Loosen the spindle nut and adjust the speed until frequency reads

400Hz, after adjustment, hold the spindle in set position with a screwdriver whilst tightening the spindle locking nut.

3.2.12 Volts adjust control

The voltage adjustment potentiometer on control allows the AC output voltage to be trimmed. caution - the 400Hzoutput voltage is preset. Do not attempt adjustment unless it is absolutely necessary. First adjustment must be carried out whilst running off load. Select the interlock/Bypass switch to Bypass and press the output ON pushbutton to close the contactor. Loosen the potentiometer spindle-locking nut, then with a test meter, measure the cable end voltage and turn the adjuster until indicated phase-neutral voltage for each phase is 115V, after adjustment, hold the spindle in its set position with a screwdriver whilst tightening the spindle-lock nut.

3.2.13 Volts amps selector switch

The phase voltage and line current can be monitored by selection of the appropriate meter channel [2].

3.3 Faults Diagnosis

Attention this equipment operates at voltages up to 200 volts AC. Due care must be exercised when fault tracing. the fault diagnosis data is presented as a series of flow diagrams and is a summary of common troubles which may arise during the operational life of the equipment. The information is as comprehensive as possible but a thorough knowledge of the operating principles and regular maintenance is required to ensure continuous trouble free operation.

The data is presented in a logical sequence from engine starting to on load conditions. Each probable fault symptom has its own flow diagram and before using the flow diagram for a particular fault symptom always refer to the preceding fault symptoms [4].

Before commencing to fault find, check the following:

- Ensure that batteries are serviceable and that they are providing a 24v Dc power supply.
- Ensure there is an adequate supply of fuel and oil for engine running.
- Ensure that all manually operated circuit breakers are ON.
- Check that all printed circuit ribbon cable connectors are secure.

If a fault develops which cannot be cleared by working to the flow diagrams, then specialist attention should be sought from Houchin Aerospace Ltd. Faults has been programed in matlab program at appendix (A).

3.4 Faults List

- Fault no.1.battery charge lamp fails to illuminate when the engine start switch is on.
- Fault no. 2 engine fails to crank when the start switch is operated to the HS position.
- Fault no. 3 engine cranks but fails to start and idle at any speed.
- Fault no. 4 malfunction of engine protection system.
- Fault no. 5 engine will not run up to service speed.
- Fault no. 6 alternator fails to excite when excite switch is operated.
- Fault no. 7 alternator gives incorrect output.
- Fault no. 8 AC output contactor fails to close and retain when bypass is selected.
- Fault no. 9 AC output contactor fails to retain when in interlock.
- Fault no. 10 .AC protection system is faulty.
- Fault no. 11TRU contactor fails to close when the DC on switch is pressed
- Fault no. 12 TRU contactor does not retain when the DC on switch is released. Volts correct.
- Fault no. 13 TRU protection system is faulty.

CHAPTER FOUR

THE MODEL OF GPU UNIT

4.1 The Model Component

The practical design is a simplified model of GPU which designed to generate voltage with frequency 400Hz and it consists of :

4.1.1 AC generator

In electricity generation, a generator is a device that converts mechanical energy to electrical energy for use in an external circuit. The source of mechanical energy may vary widely from a hand crank to an internal combustion engine. Generators provide nearly all of the power for electric power grids. the reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities. Many motors can be mechanically driven to generate electricity and frequently make acceptable manual generator. Used three phase generator with brushes and 8 poles.

4.1.2 DC motor

A DC motor is any of a class of electrical machines that converts direct current electrical power into mechanical power. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor. Most types produce rotary motion; a linear motor directly produces force and motion in a straight line.

DC motors were the first type widely used, since they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor can

operate on direct current but is a lightweight motor used for portable power tools and appliances. Larger DC motors are used in propulsion of electric vehicles, elevator and hoists, or in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications.

We used Permenant DC motor as a prime mover have rating power of 90W and rating voltage of 90V and current of 1A [2].

4.1.3 Electronic Speed control unit

An electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor.

An ESC can be a stand-alone unit which plugs into the receiver's throttle control channel or incorporated into the receiver itself, as is the case in most toy-grade R/C vehicles. Some R/C manufacturers that install proprietary hobby-grade electronics in their entry-level vehicles, vessels or aircraft use onboard electronics that combine the two on a single circuit board [5].

4.1.4 Excitation circuit 12VDC

An electric generator or electric motor consists of a rotor spinning in a magnetic field. The magnetic field may be produced by permanent magnets or by field coils. In the case of a machine with field coils, a current must flow in the coils to generate the field, otherwise no power is transferred to or from the rotor. The process of generating a magnetic field by means of an electric current is called excitation.

4.1.5 conveyor belt

A conveyor belt is the carrying medium of a belt conveyor system (often shortened to belt conveyor). A belt conveyor system is one of many types

of conveyor systems. A belt conveyor system consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium—the conveyor belt—that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley. There are two main industrial classes of belt conveyors; Those in general material handling such as those moving boxes along inside a factory and bulk material handling such as those used to transport large volumes of resources and agricultural materials, such as grain, salt, coal, ore, sand, overburden and more.

4.1.6 Trailer (vehicle)

A trailer is generally an unpowered vehicle towed by a powered vehicle. It is commonly used for the transport of goods and materials. Sometimes recreational vehicles, travel trailers, or mobile homes with limited living facilities, where people can camp or stay have been referred to as trailers. In earlier days, many such vehicles were towable trailers [3].

4.1.7 Indicator

A malfunction indicator lamp (MIL), also known as a check engine light, is a tell-tale to indicate malfunction of a computerized engine-management system. It is found on the instrument panel of most automobiles. When illuminated, it is typically either an amber or red color. On vehicles equipped with OBD-II, the light has two stages: steady (indicating a minor fault such as a loose gas cap or failing oxygen sensor) and flashing (indicating a severe fault, that could potentially damage the catalytic converter if left uncorrected for an extended period). When the MIL is lit, the engine control unit stores a fault code related to the malfunction, which can be retrieved with a scan tool and used for further diagnosis, the diagnosis maybe retrieved without a scan tool in some car models. The malfunction indicator lamp usually bears the legend CHECK ENGINE, SERVICE ENGINE SOON, or a pictogram of an engine. In the United States, specific functions are required of the MIL

by EPA regulations.[lamp 4 to indicate the power is connected to the circuit, lamp1 to indicate there is output, lamp 2 to indicate that the circuit is running and Lamp 3 to indicate that the circuit is stopped.

4.1.8 Contactors and push button switches

A contactor is an electrically controlled switch used for switching an electrical power circuit, similar to a relay except with higher current ratings.[1] A contactor is controlled by a circuit which has a much lower power level than the switched circuit.

Contactors come in many forms with varying capacities and features. Unlike a circuit breaker, a contactor is not intended to interrupt a short circuit current. Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand, to large devices approximately a meter on a side.

A push-button (also spelled pushbutton) or simply button is a simple switch mechanism for controlling some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal.[1] The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed or pushed. Buttons are most often biased switches, though even many un-biased buttons (due to their physical nature) require a spring to return to their un-pushed state. Different people use different terms for the "pushing" of the button, such as press, depress, mash, hit, and punch.

4.1.9 Conductors for connecting circuit

In physics and electrical engineering, a conductor is an object or type of material that allows the flow of an electrical current in one or more directions. A metal wire is a common electrical conductor.

In metals such as copper or aluminum, the mobile charged particles are electrons. Positive charges may also be mobile, such as the

cationic electrolyte(s) of a battery, or the mobile protons of the proton conductor of a fuel cell. Insulators are non-conducting materials with few mobile charges that support only insignificant electric currents[2].

4.1.10 Step down transformer 220/110

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive force within a conductor which is exposed to time varying magnetic fields. Transformers are used to increase or decrease the alternating voltages in electric power applications various specific electrical application designs require a variety of transformer types. Although they all share the basic characteristic transformer principles, they are customize in construction or electrical properties for certain installation requirements or circuit conditions.

4.2 The model Operation

As shown in figure 4.1 when the circuit supplied with power lamp 4 will turn on. then press contactor 2 which supply the transformer thus the circuit been ready and lamp 3 will turn on. then press contactor 3 the generator will start running. then press contactor 1 the measurement devices will read the output. we can use potentiometer R2 of the speed control unit to control the speed. To stop the unit press stop switch [3].

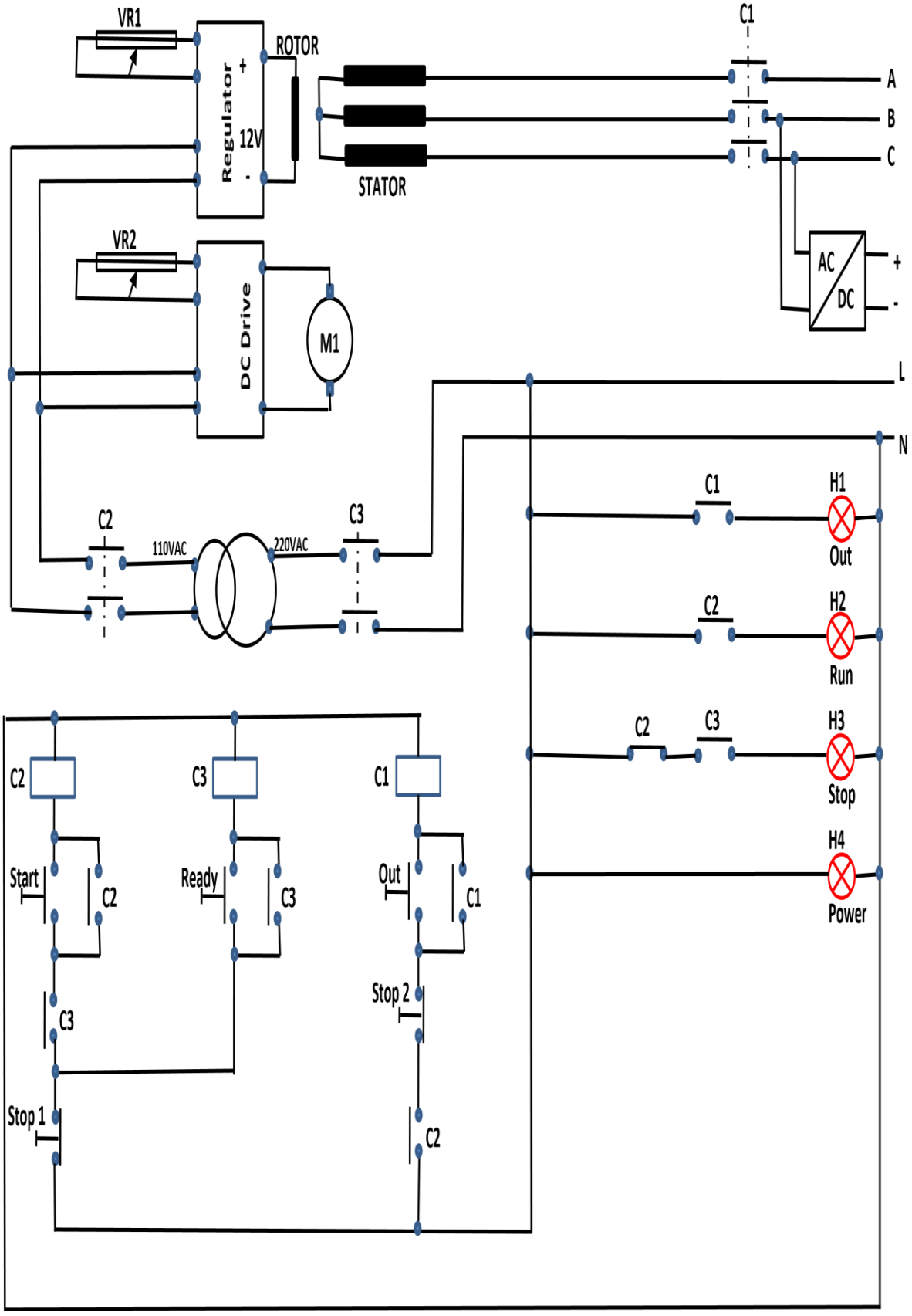

Figure 4.1 The control circuit of the model

Figure 4.2 Model main panel

Figure 4.3 The model

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It has been studied the ground power unit generally included types of ground power units, electrical characteristic, frequency converters, final power delivery and comparison between four different types of GPU.

And in detail the GPU model D690/140KVA/DV has been studied included the components, operation and troubleshooting.

It was also practical design of ground power unit has been done. while giving the same output in terms of voltage and frequency. difficulties that were during the study few previous studies on the same topic and inaccessibility to modern maintenance unit places.

5.2 Recommendations

The unit under study Its considered as very important part at any airport so it must be more attention by many researchers and students.

Now days, it became the use of mobile ground power type very limited and become a trend to use fixed ground power type because it has a lot of features not available in mobile ground power which became a secondary option.

Accordingly, it is recommended have been fixed ground power the focus of studies later containing comparisons between the two types so the benefit.

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APPENDIX (A)

FAULT DIAGNOSIS OF GPU MODEL D690

Faults Program

```
z=1;
while z
clear
clc
y=input('If you want go to troubleshooting selcet1 or slecet2 to open abbreviations');
switch(y)
case 1
x=input('Enter the NUMBER of Fault');
switch(x)
case 1
disp('Battery charge lamp fails to illuminate when the engine start is on')
pause(5)
disp('does battery charge lamp light?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp ('thank you')
elseif str == 'N';
disp('Is F1 on engine interface P.C.B O.K.')
prompt = 'Do you want more? Y/N [Y]: ';
str1 = input(prompt,'s');
if str1 == 'N';
disp('replace F1')
elseif str1 == 'Y';
disp('Is F4 on contactor assembly O.K.?')
```

```
prompt = 'Do you want more? Y/N [Y]: ';
str2 = input(prompt,'s');
if str2 == 'N';
disp('Replace F4')
elseif str2 == 'Y';
disp('Is battery charge lamp faulty?')
prompt = 'Do you want more? Y/N [Y]: ';
str3 = input(prompt,'s');
if str3 == 'Y';
disp('Replace bulb')
elseif3  str=='N'
disp('check battery supply and wiring to start switch and battery charge lamp')
end
end
end
end
disp('select switch on')
case 2
disp('Engine fails to crank when the start switch is operated to the Hs position
');
pause(5)
disp('Does engine crank O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif  str=='N'
disp('Is there 24 D.C. at start relay?')
prompt = 'Do you want more? Y/N [Y]: ';
str1 = input(prompt,'s');
```

```
if str1 == 'Y';
disp('Check start relay, start sol and start motor ')
elseif  str1=='N'
disp('Check wiring to start switch, idle/service switch and start relay')
disp('Change RL1 on engine interface P.C.B.')
end
end
case 3
disp('Engine cranks but fails to start and IDEL at any speed')
pause(5)
disp('Switch start switch ON')
pause(5)
disp('Does actuator arm move to open throttle?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Does engine run at correct idle speed?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str1 == 'Y';
disp('Thank you')
elseif str1 =='N';
disp('Does engine run at any speed?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str2 == 'Y';
disp('Check wiring to idle/service switch and speed adjust pot')
disp('Change governor P.C.B.')
elseif str2=='N';
disp('Check wiring to fuel sol')
```

```
disp('check fuel system')
end
end
elseif str== 'N';
disp('Has a link been fitted to engine p.u. test on engine interface P.C.B.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Fit a temporary link across engine P.U.')
elseif str =='Y';
disp('Is speed probe healty LED on govrener P.C.B. lit?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Check speed probe')
elseif str == 'Y';
disp('Is output LED on govrner p.c.b. lit ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Check wiring to speed adjust pot')
disp('Change governor p.c.b.')
elseif str== 'Y';
disp('Is actuator wiring O.K.?')
disp('Is fuse on governer p.c.b O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Change fuse')
elseif str == 'Y';
```

```
disp('Change governer p.c.b.')
end
end
end
end
end
case 4
disp('Mafunction of engine protection system')
pause(5)
disp('is the engine fault indicate ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Does a running engine shut down ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
   disp('Thank you')
elseif str =='N';
disp('change engine p.u. p.c.b.')
end
elseif str =='N';
disp('Is fault signal from engine p.u. O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
   disp('correct as necessery')
elseif str == 'Y';
   disp('Has engine p.u. p.c.b. been changed ?')
   prompt = 'Do you want more? Y/N [Y]: ';
```

```
str = input(prompt,'s');
if str == 'Y';
   disp('Change fault display p.c.b.')
elseif str == 'N';
   disp('Change engine p.u. p.c.b.')
end
end
end
case 5
disp('Engine will not run up to service speed')
pause(5)
disp('switch idle/service switch to service')
disp('Does engine accelerate O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('check wirinig to idle/service switch & speed adjust pot')
disp('Check fuel system')
elseif str == 'Y';
disp('is engine running at correct speed ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str == 'N';
disp('Does speed adjust pot,adjust to correct speed?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
```

```
elseif str =='N';
disp('check speed adjust pot wiring')
disp('change governor p.c.b.')
end
end
end
case 6
disp('Alternator fails to excite when excite switch is operated')
pause(5)
disp('Keep excite p.b. pressed')
pause(2)
disp('Does alternator excite ?')
 prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str == 'N';
disp('Check wiring to idle/service switch,excite p.b. & A.V.R. ')
disp('Is CB1 closed on contactor assembly')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Close CB1')
elseif str == 'Y';
disp('Is wiring to A.V.R. O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Correct')
elseif str == 'Y';
```

```
disp('Operte Test 1 PB on A.V.R O.K.?')
disp('Is LED8 on A.V.R. lit ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Operete test 1& test 2 PBs on A.V.R. ')
disp('Is LED 8 on A.V.R. extingushed ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Change A.V.R.')
elseif str == 'Y';
disp('Check field wiring')
end
elseif str=='N';
disp('Is LED 5 on A.V.R. lit ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Check field wiring')
elseif str == 'N';
disp('Change A.V.R.')
end
end
end
end
end
case 7
disp('Alternator gives incorrect output')
pause(5)
```

```
disp('keep excite p.b. pressed')
pause(2)
disp('Are output volts correct?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str == 'N';
disp('Can volts be adjusted correctly by volts adjust pot ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Adjust volts')
elseif str == 'N';
disp('Are fuses F1,F2,F3 on contactor assy O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Replace fuses')
elseif str == 'Y';
disp('Check wiring to volts adjust pot')
disp('Change A.V.R.')
end
end
end
case 8
disp('AC protection system is faulty')
pause(5)
disp('Switch to BYPASS set running and excited to correct voltage')
pause(2)
```

```
disp('Press and relese a.c. output on p.b.')
pause(2)
disp('Does a.c. output contactor close and latch?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Check wiring to on p.b. and interlock/bypass switch')
elseif str == 'Y';
disp('Is a.c. power ON lamp it ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str == 'N';
disp('check lamp bulb and wiring to lamp')
end
end
case 9
disp('AC output contactor fails  to retain when in intelock')
pause(5)
disp('Bypass/intrelock switch in INTERLOCK,set running and excited to correct output volts ')
pause(2)
disp('Press and relese a.c. output ON p.b.')
pause(2)
disp('Does a.c. output contactor close and retain ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
```

```
elseif str == 'N';
disp('Is INTERLOCK LED D3,D on alt interface p.c.b. lit?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Check aircraft intrelock supply')
elseif str == 'Y';
disp('Change interlock relay (RL1,RL2) on alternator interface p.c.b.')
end
end
case 10
disp('Ac protection system is faulty')
pause(5)
disp('Alternator excited,outpuy contator closed')
pause(2)
disp('Set up fault condition')
pause(2)
disp('Does a.c. output contactor trip and and alterntor de-excite?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Change alterntor p.u.')
elseif str == 'Y';
disp('Does fault display show fault?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str == 'N';
disp('change fault display p.c.b.')
```

```
end
end
case 11
disp('TRU contactor fails to close when the DC on switch is pressed')
pause(5)
disp('Altenator excited')
pause(2)
disp('Press and hold d.c. output p.b.')
pause(2)
disp('Does d.c. power on lamp light?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Does d.c. digital meter indicate approx 28v d.c.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Check wiring to contactor')
elseif str =='Y';
disp('Thank you')
end
elseif str== 'N';
disp('Is F5 on contactor assembly O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Change F5')
elseif str == 'Y';
disp('Is wiring to d.c. power ON lamp and p.b.s O.k.')
prompt = 'Do you want more? Y/N [Y]: ';
```

```
str = input(prompt,'s');
if str == 'N';
disp('corret wiring')
elseif str == 'Y';
disp('Is lamp bulb O.K.? ')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Replace bulb')
elseif str == 'Y';
disp('Change RL1 on d.c. interface p.c.b.')
end
end
end
end
case 12
disp('TRU contactor does retain when the DC on switch is released volts correct')
pause(5)
disp('Alternator excited split pin bridged')
pause(2)
disp('Press and release d.c. output on p.b.')
pause(2)
disp('Does d.c. power ON lamp stay lit ?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str == 'N';
disp('Is F6 ON contactor assembly O.K.')
```

```
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Replace F6')
elseif str == 'Y';
disp('Has alink been fitted to dc p.u. test on dc interface p.c.b.')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Fit link')
elseif str == 'Y';
disp('Is interlock LED D4 on d.c. interface p.c.b lit ? ')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('change RL2 on d.c. interface p.c.b.')
elseif str =='Y';
disp('Is F7 on contactor assembly O.K.?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('Replace F7')
elseif str == 'Y';
disp('Check CON1 aux contact and output cable interlock wiring')
end
end
end
end
end
case 13
```

```
disp('TRU protection system is faulty');
pause(5)
disp('Alternator excited D.C. output ON')
pause(2)
disp('Set up fault condition')
pause(2)
disp('Does TRu contator trip?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'N';
disp('change d.c. p.u. p.c.b.')
elseif str == 'Y';
disp('Does fault display show fault?')
prompt = 'Do you want more? Y/N [Y]: ';
str = input(prompt,'s');
if str == 'Y';
disp('Thank you')
elseif str== 'N';
disp('Change fault display p.c.b.')
end
end
end
case 2
prompt = 'write the abbreviations ';
str = input(prompt,'s');
switch str
   case 'N'
disp('No')
case 'Y';
   disp('Yes');
```

```
case 'ALT';
   disp('Alternator');
   case 'ASSY';
   disp('Assembly');
   case 'A.V.R';
   disp('Automatic Voltage Regulator');
   case 'AUX';
   disp('Auxiliary');
   case 'CB';
   disp('Circuit Breaker');
   case 'LED';
   disp('Light Emitting Diode');
   case 'P.C.B.';
   disp('Printed Circuit Board');
  case 'P.U.';
   disp('Protection Unit');
   case 'POT';
   disp('Potentioeter');
   case 'PB';
   disp('Pushbutton');
   case 'SOL';
   disp('Solenoid');
   case 'T.R.U';
   disp('Transforer Rectifier Unit');

end
pause(5)
end
z=input('If you want to end the program select0 or select1 to return to
program ');
```

```
end
disp('Thank for using this program ');
pause(2)
disp('Good luck');
pause(2)
break
.....
```

APPENDIX (B)

THE MODEL D690 INFORMATION

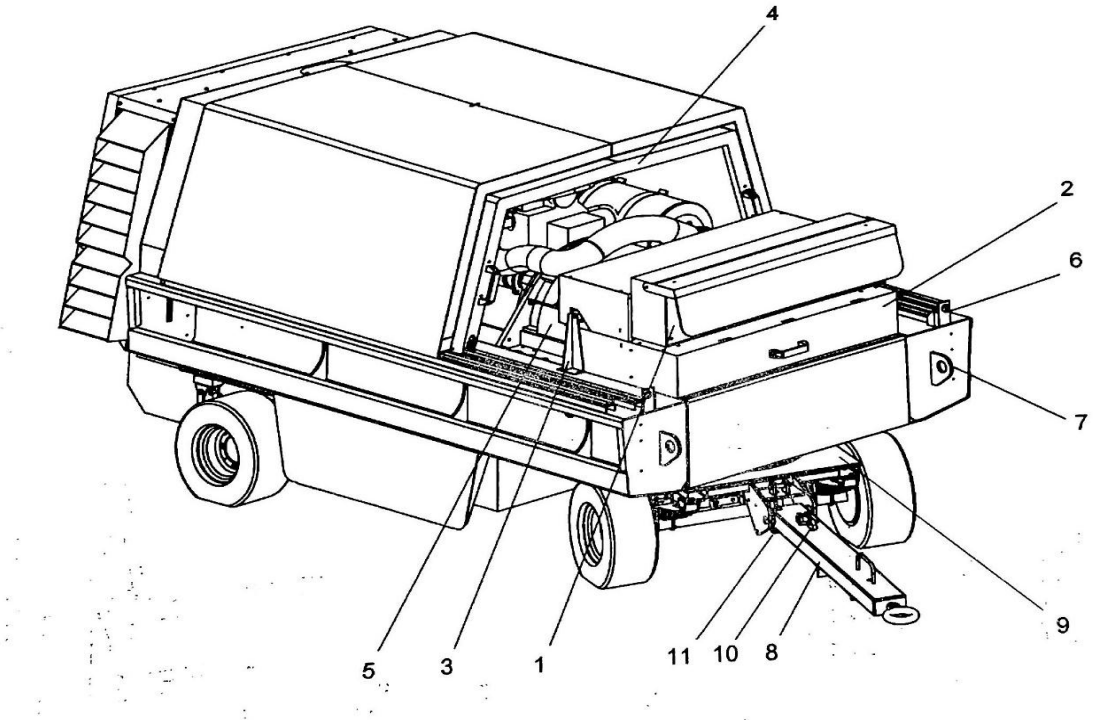

Figure 5.1: Typical view with control canopy retra

1. Control panel
2. Control panel support
3. Hinge bar control panel support
4. Canopy section - control panel support
5. 400Hz alternator
6. Location for fastening canopy
7. Tie down point for ground unit
8. Towbar
9. Steering turntable
10. Towbar catch
11. Brake compensator

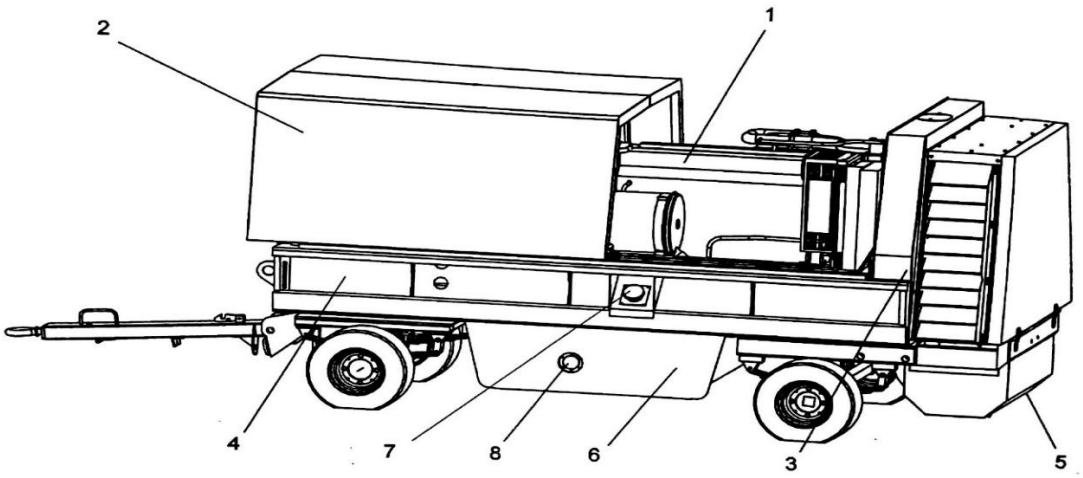

Figure 5.2: Typical view with engine canopy retracted

1. Engine
2. Engine canopy section
3. Location for fastening canopy
4. Output cable stowage
5. Engine exhaust outlet
6. Fuel tank
7. Fuel filler
8. Fuel contents gauge

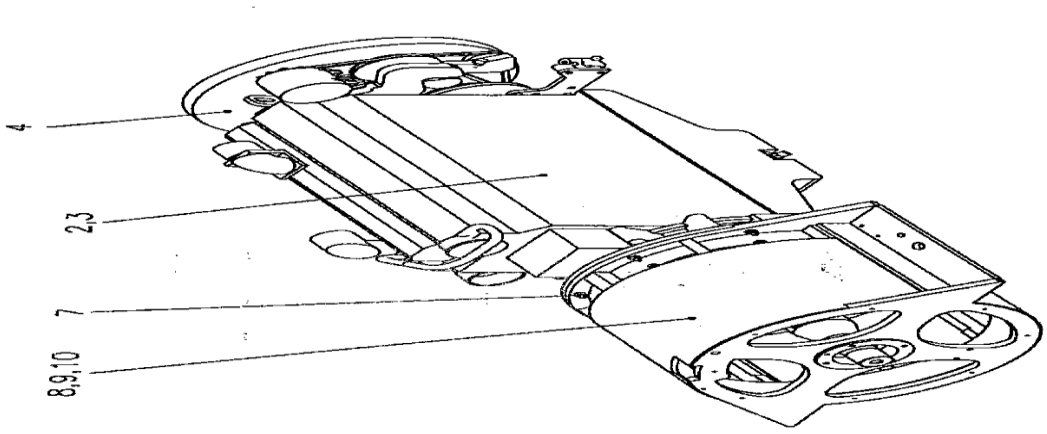

Figure 5.3: Engine assembly

Table 5.1 : Engine assembly description

Item No.	Description	Units per assy.
1	Engine; assembly	1
2	Engine, bare(for spare parts refer to Deutz Engine parts list)	1
3	Mounting; Engine	1
4	Engine, fan	1
5	BTM Waterway support	1
7	plate, adaptor; flywheel housing attaching parts	1
7a	bolt, adaptor plate to alternator, m10 x 60mm long; hex.	8
7b	nut; torque, m10	8
7c	washer, spring, m10	8
7d	screw, adaptor plate to engine, m8 x 30mm long, hex. HD	12
7e	washer, spring; m8	12
8	alternator: 140KVA	1
9	screw; coupling; flywheel to alternator PTO plate	8
10	plain, m10	8

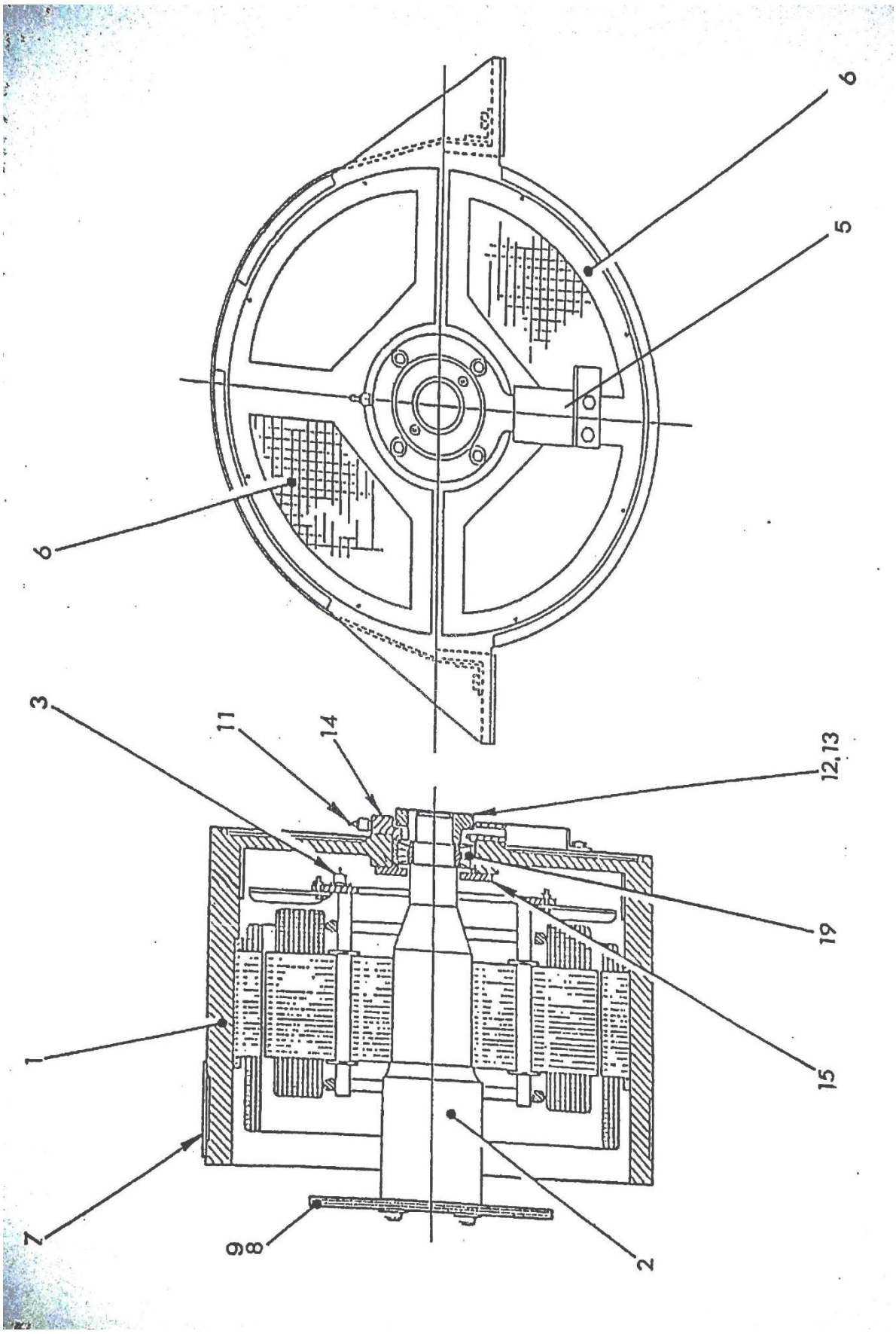

Figure 5: Alternator assembly

Table 5.2 Alternator assembly description

Item No.	Description	Units per assy.
1	Stator, assembly	1
2	Rotor; assembly	1
3	Diode; rotating rectifier	5
5	Grease Tray	1
6	GUARD	2
7	GUARD; stator; flywheel end	1
8	P.T.O. PLATE	6
9	CLAMP PLATE	1
11	NIPPLE; grease; 1/8" BSP	1
12	RING; grease thrower	1
13	SETSCREW; M8 x 10mm long; socket hd	1
14	PLATE; race, outer	1
15	PLATE; race, inner	1
19	BEARING; type 22210 spherical	1

Table 5.3: Control panel assembly – digital description

Item No.	Description	Units per assy.
1	Switch: start key operated. circuit Ref. 5s1	1
2	Hourcounter. circuit Ref. 5M1	1
3	Body; lamp; indicating. Circuit Ref. 5LP1	7
4	LENS; red. Circuit Ref. 5LP1	2
5	LENS; clear. Circuit Ref. 5LP5; 6	3
6	LENS, amber. Circuit Ref. 5LP7	7
7	LAMP; filament; 24V/2.8W: MES; E10/13. Circuit Ref. 5LP1; 5-8; 10	1

8	SWITCH; toggle; panel lamps. Circuit Ref. 5S3	1
9	SWITCH; toggle; idle/service. Circuit Ref. 5S2	1
10	Potentiometer; 10 K ohm; 2W; volts adjust. Circuit Ref. 5R2	1
11	Potentiometer: 1 K ohm; 2W; speed adjust. Circuit Ref.	2
12	Lock, potentiometer	2
13	KNOB; digital meter rotary switch	2
14	CAP; black, digital meter rotary switch	2
15	Stator; digital meter rotary switch	2
16	DIAL: figure; digital meter rotary switch	2
17	Pushbutton. Circuit Ref. 5S4-7; 9; 11; 12	7
18	Actuator: pushbutton; red. Circuit Ref. 5S5 7; 12	3
19	Actuator: pushbutton; green. Circuit Ref. 5S4, 6; 11	3
20	Actuator, pushbutton; blue. Circuit Ref. 5S9	1
21	Block: contact, for pushbutton. Circuit Ref. 5S5; 7; 12	
22	Block: contacts for pushbutton. Circuit Ref. 5s4; 6, 9, 11	9
23	Printed Circuit; assembly AC. digital meter	1
24	Printed Circuit; assembly. DC digital meter	1
25	Lens; for ACs and DC. digital meter displays	2
26	Printed Circuit; assembly; fault display	1
27	Lens; for fault display	1
33	Lamp; panel illumination. Circuit Ref. LP2-4	3

34	LAMP; filament, 24VI4W: SBC. Circuit Ref. LP2-4	3
35	Cover: Perspex; control panel	1
-36	Support Strap; assembly	2
-37	Contactor Panel: assembly	1
38	Support; control panel	1
39	Handle: panel support	1
40	Mounting: flexible; control panel	4
-41	Enclosure: contactor panel	1
-42	Fastener: toggle	4
43	Socket	1
-44	RELAY: 2 pole c/o 24Vdc coil. Circuit Ref. R1-2	3
-45	RELAY: socket 224-730. Circuit Ref. R12-4	3
-46	FUSE terminal 111033.03. Circuit Ref. F9	1
-47	Fuse Link: quick action 10 amp. Circuit Ref F9	1
-48	Terminal: 0115 116.07	12
-49	RESISTOR: 1K ohm +l-1% 0.5W. Circuit Ref R1	1

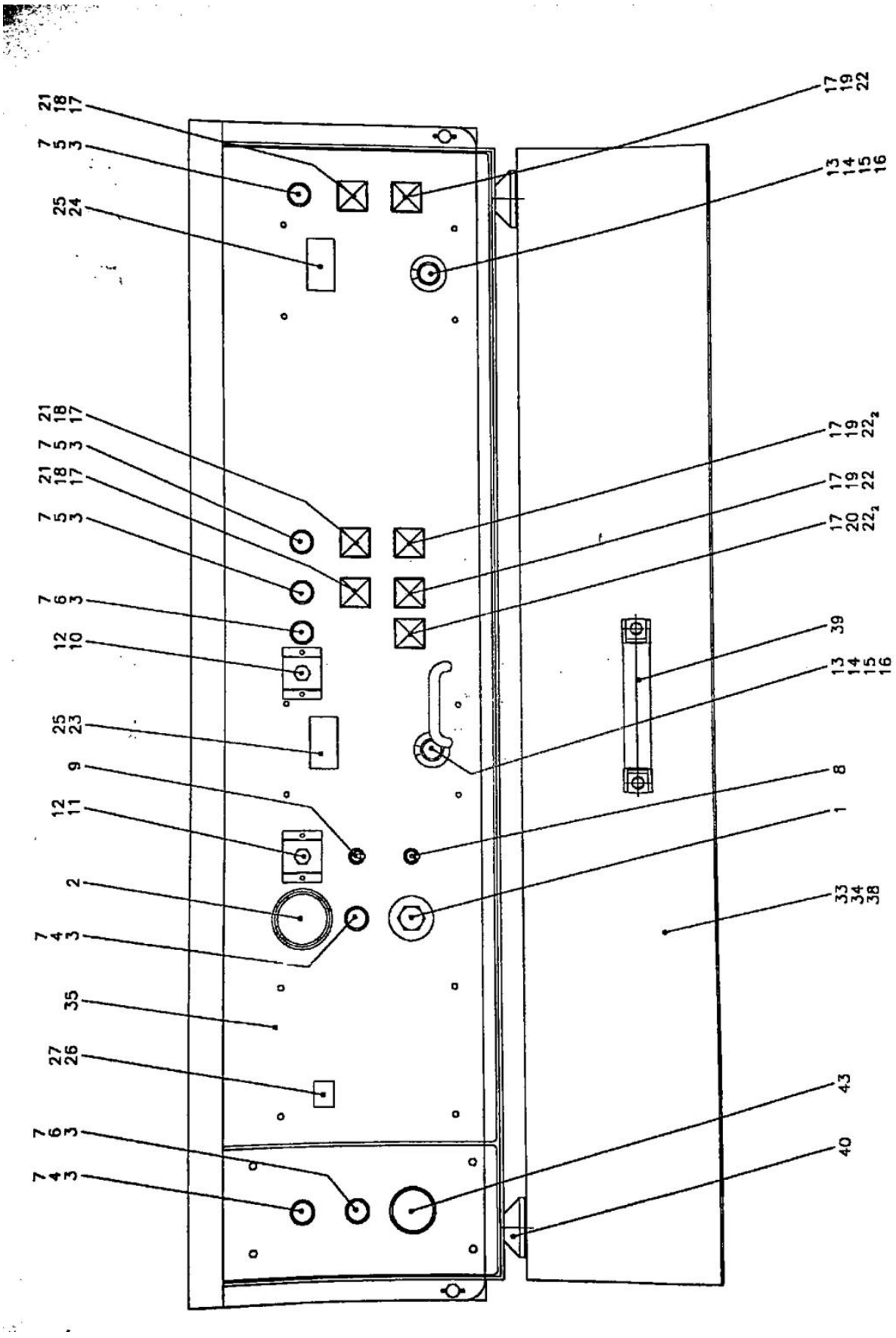

Figure 5.5: Control panel assembly - digital

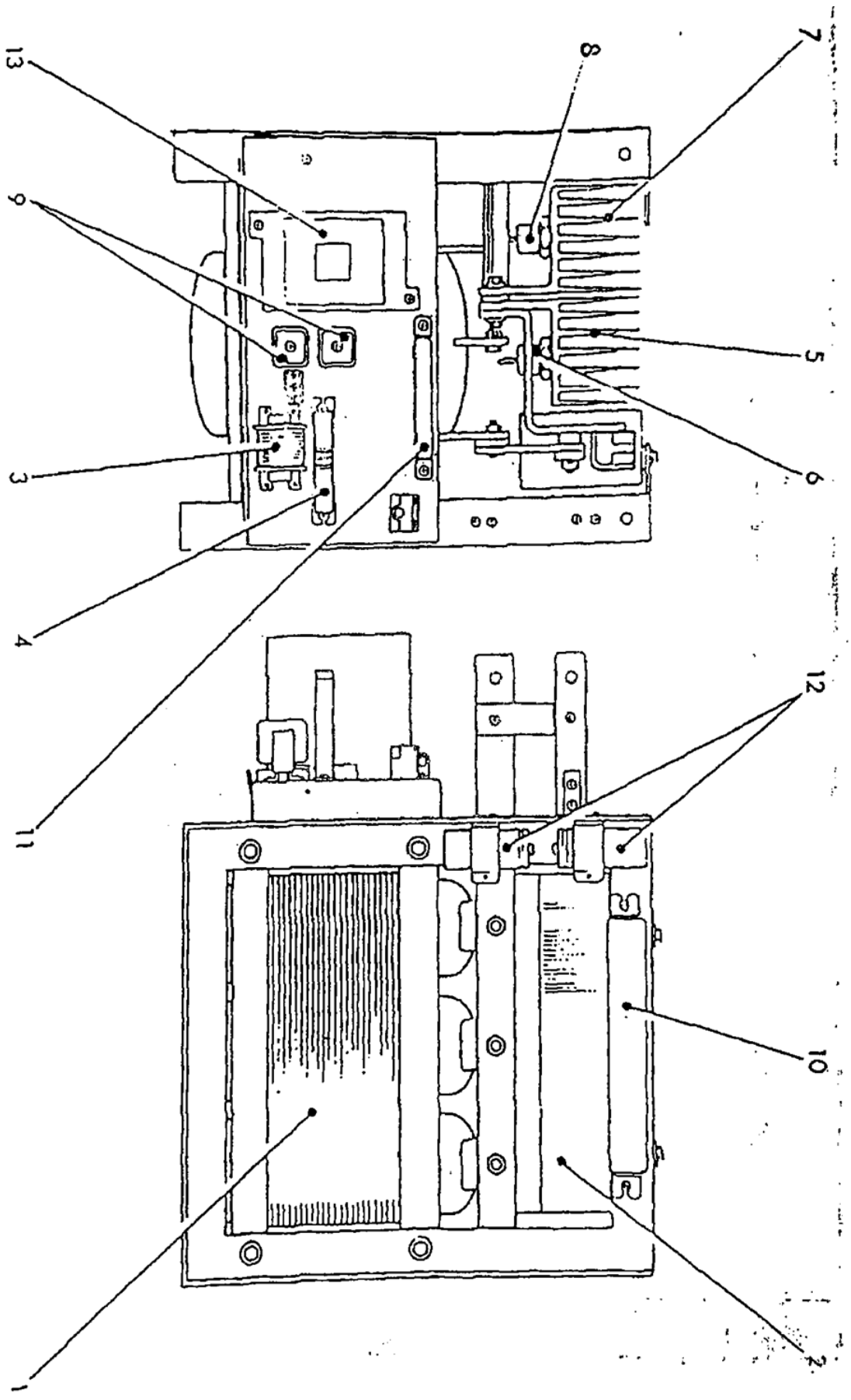

Figure 5.6: Transformer rectifier unit assembly

Table 5.4: Transformer rectifier unit description

Item No	Description	Units per assy.
1	TRANSFORMER. Circuit Ref. 6T1	1
2	CHOKE. Circuit Ref. 6L1	1
3	TRANSFORMER: current. Circuit Ref. 6CT1	1
4	TRANSFORMER; current Circuit Ref.6CT2	1
5	HEATSINK; assembly	1
6	DIODE; high power	3
7	HEATSINK; assembly	1
8	DIODE; high power	3
9	RECTIFIER; bridge. Circuit Ref. 6BR1; 2	2
10	RESISTOR; 6.8 ohms 1-10%; 200W. Circuit Ref. 6R1	1
11	RESISTOR; tapped; 40 Ohm 1-10%; 40W Circuit Ref. 6R2	1
12	CAPACITOR: 4700 MFD; 40V D.C. Circuit Ref. 6C1: 2	2
13	CONTACTOR. Circuit Ref. 6CON1	1
-13A	AUXILIARY CONTACT BLOCK	2
-13B	COIL: 24V D.C.	1
-13C	MAIN CONTACT UNIT	1
14	flexible	4