AUTO CHANGEOVER TO GENERATOR ON MAINS FAILURE

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An auto-changeover on mains failure (AMF) system comprising mains and standby sources of power supply continuously monitors the incoming mains and in case of its interruption, starts the standby diesel generator (DG) set, monitors its output and then transfers the load to the DG set.

Here is a construction project that utilises off-the-shelf readily available switchgear and integrates it with the indigenously designed logic control circuitry to automatically start the standby supply source on failure of the mains 3-phase supply and stop the DG set on resumption of mains. This system costs about 40 per cent less than the systems supplied by AMF panel designers.

System features

1. The original configuration/operation of the DG set as also its control panel is not disturbed. That means manual start/stop operation of the DG set and its control panel functions of monitoring its 3-phase output are still available.

2. Before changeover either to the DG set or to mains, the selected source is checked for single-phasing, phase reversal, and under- and over-voltage conditions. If the conditions are not fulfilled, changeover to the faulty source is inhibited.

3. Suitable delays have been provided in start and stop control of the DG set.

4. The maximum number of cranking (starting) attempts is presettable by the user.

5. For indicating the mode of operation, selected source of supply, low-battery condition, etc, status-indication LEDs have been provided on the logic control panel.

6. A buzzer warns the operator of low-battery state and over-cranking attempts. It can be reset/disabled by the operator. However, the low-battery indication LED will remain lit as long as the battery voltage remains low.

7. When manual mode is selected, the DG set can be electrically started from the logic panel itself via pushbuttons. Latching relays ensure that either the start or the stop operation is performed at a time.

8. Use of the industrial changeover switchgear ensures preferential selection of mains, in case both the DG set supply and mains are available. Mechanical interlocking and tripping before selection arrangements ensure that the two sources are never paralleled.

9. The system is capable of flawless operation under potentially noisy (electrical) environments due to the use of a hardware debounce and feedback circuitry.

10. The logic panel has been designed using discrete ICs, relays and other passive/active devices. Hence understanding the logic is easy and the changes required to meet the peculiarities of the individual standby supply source can be easily implemented.

11. The logic circuit con-

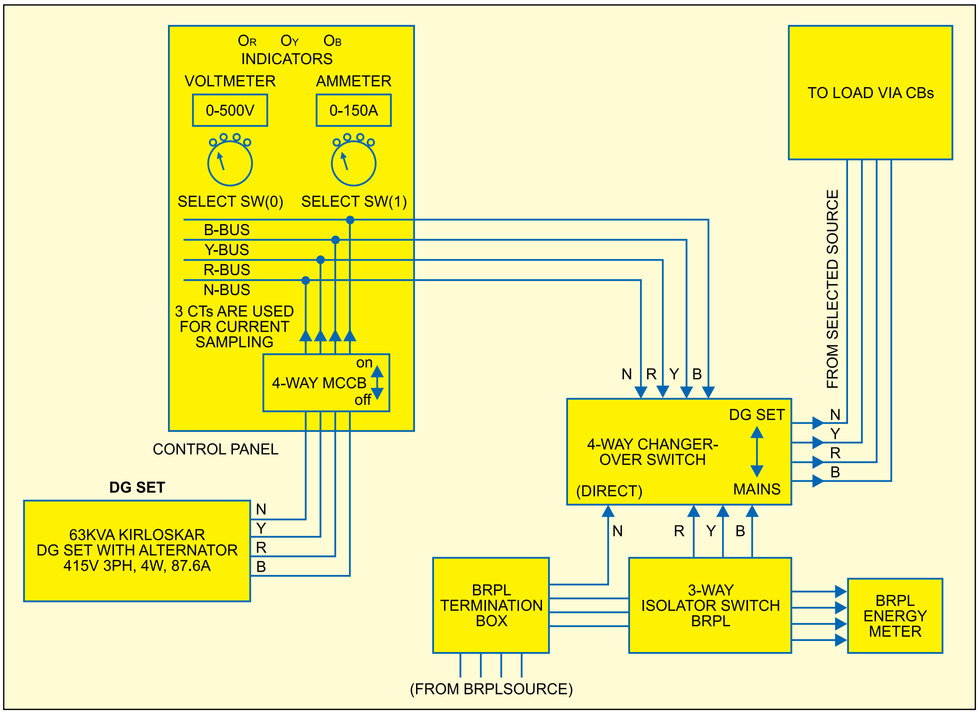


Fig. 1: Line/block diagram of the manual changeover system that existed before changeover to AMF

sumes minimal power, as most of the ICs used are CMOS.

Manual changeover system

Fig. 1 shows the block diagram of the manual changeover system. The 3-phase, 4-wire output of the DG set is terminated on the control panel via the 4-way isolator (moulded-case circuit breakers (MCCBs)). The control panel has the usual voltage and ampere meters with current transformers (CTs) and selector switches for monitoring all the three phases. (Some panels may have a power factor meter as well.) The 3-phase output of the control panel is routed to a 4-way manual changeover switch. The mains 3-phase power is also terminated on the manual changeover switch via an isolator switch and energy meter. The source (mains or DG set output) selected by the manual changeover switch is routed via MCCBs to feed the desired loads.

The AMF system has been designed around a Kirloskar HA series engine with a 3-phase, 4-wire, 415V AC, 50Hz alternator capable of delivering a maximum of 87.6 amperes per phase at a power factor (PF) of 0.8. The alternator uses 300V DC excitation at 4.2A.

The DG set is equipped with:

1. Flywheel with starter ring
2. 12V electric starter
3. Mechanical shutdown lever
4. Battery charging dynamo
5. Engine instrument panel consisting of:
   - Off/on/start key
   - Lube-oil pressure gauge
   - Battery charging ammeter
   - Hour meter

Fig. 2 shows the block diagram of the electrical system of the DG set. It differs slightly from the diagram printed on the DG set's instrument panel.

The DG set is shut off by mechanically pulling a lever, which cuts off the fuel supply to the injectors and the engine comes to a halt in eight to ten seconds. The knowledge of functioning of starting circuit/components and charging circuit/components is necessary for proper understanding the design of AMF logic system (to be described later).

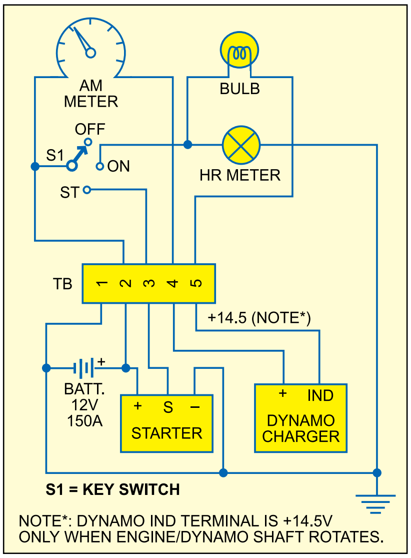


Fig. 2: Schematic block diagram of the DG set's electrical system

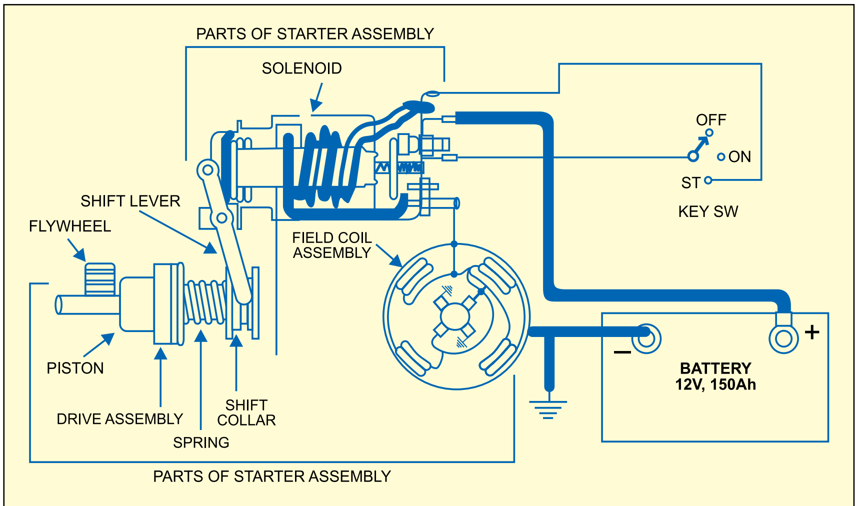
DG set starting/cranking circuit

Fig. 3(a) shows the circuit for starting the DG set. The starter assembly comprises a starter, solenoid assembly as well as shift lever and drive assembly. It is housed inside a metallic body with cut near the drive assembly for engaging its geared pinion with the flywheel ring gear of the DG set when the solenoid is energised. The body of the starter assembly is grounded/connected to the negative terminal of the battery.

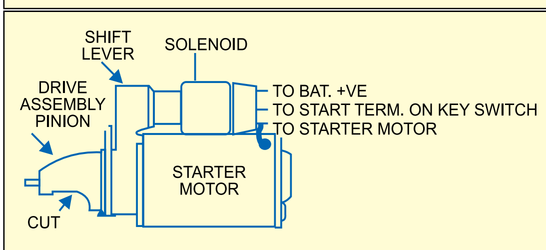
Fig. 3(b) shows the complete starter motor assembly. It is similar to the starter assembly fitted on your car.

When the key switch is shifted to 'Start' position, the starter solenoid energises to cause the solenoid plunger to move the shift lever, which engages its pinion with the engine flywheel ring gear. The movement of the plunger also closes the main solenoid contacts, applying +12V battery voltage to the starter motor through solid contacts to allow the starter motor to draw 150-200 amperes of current for overcoming the inertia of the engine. Once the engine starts, the pinion will overrun, protecting the armature from excessive speed and the flywheel from damage. When the key switch is released, the plunger-return spring disengages the pinion.

Caution. Never operate the starter

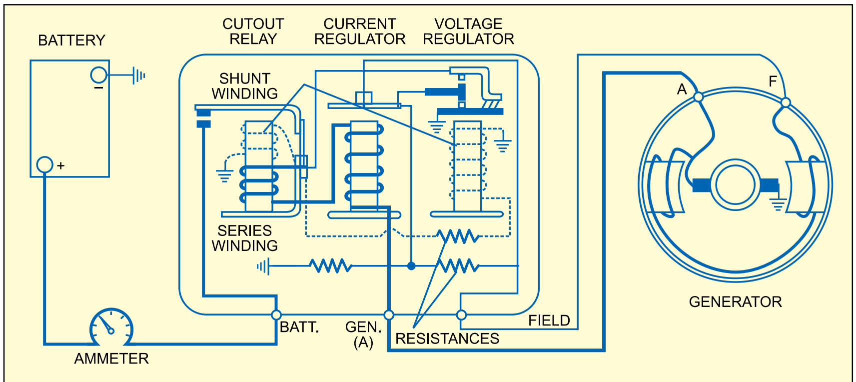


(a) PARTS OF THE DG SET STARTING SYSTEM



(b) STARTER MOTOR ASSEMBLY

Fig. 3: The DG set starting system (above) and starter motor assembly (below)



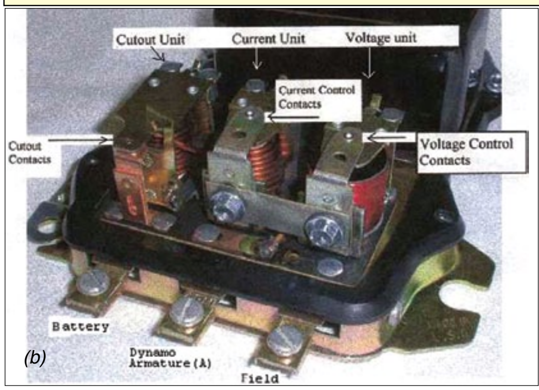


Fig. 4: Schematic diagram of a typical three-unit electromechanical regulator (above) and photograph of a typical 3-unit electromechanical regulator (below)

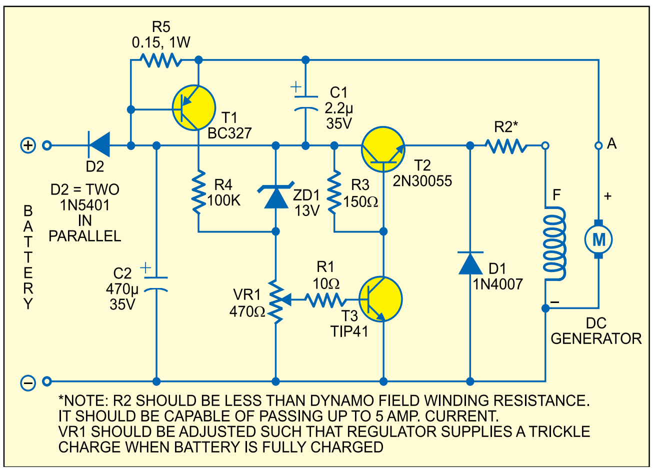


Fig. 5: A typical solidstate electronic regulator with reverse current protection for 12V battery

for more than 15 seconds at a time as excessive cranking can cause overheating of the starter. After each cranking attempt, allow the starter to cool for at least a minute.

Battery charging circuit and components

The charging current for the battery is supplied by the dynamo (also called 'generator'). A generator is like a motor in reverse. Instead of supplying the current to rotate the motor's shaft, we rotate or spin the dynamo's shaft to generate electricity. The dynamo rotor is mechanically coupled to the engine's shaft through a V-belt and pulley arrangement. The current generated in its armature is AC and not DC.

Commutators on its shaft are used to rectify the AC current. Two spring-loaded brushes slide on the commutators. One brush is connected to ground and the other is connected to the main output of the generator (the positive terminal marked 'A' for armature). As the armature/commutator assembly rotates, the brushes touch different contacts on the commutator such that the polarity of the current moving into and out of the armature commutators is always connected to the correct brushes. The net effect of this operation is that the generator output is DC even though the current inside the armature windings is AC.

Three-unit electromechanical regulator. Since the dynamo output is a function of the engine speed, the average DC output may vary. A voltage/current regulator combined with a reverse-current cut-out is used to regulate the output between 13.8V and 14.2V, which is considered to be appropriate for charging a 12V lead-acid battery. The cut-out prevents battery discharge into the generator when its output voltage is below that of the battery.

Fig. 4 shows a typical 3-unit external electromechanical regulator used for the purpose. It comprises three relays. Two of the relays have a shunt and series windings, respectively, while the third (used for cut-out function) employs mixed series and shunt windings. The regulator may also be installed within the dynamo housing itself. A full description of its working principle is given inside the box on the next page.

Solidstate (electronic) regulator. Some newer versions employ solidstate regulators with reverse-current protection. A typical solidstate regulator circuit is shown in Fig. 5. The output voltage of this regulator is held constant by 13V zener diode ZD1 in series with potmeter P1. P1 is adjusted such that when the battery is fully charged to roughly 13.8V, the field current of the generator is adequate to maintain a trickle charge current of 50 to 100 mA (through armature via 0.1-ohm resistor R5) to replenish the battery charge.

Initially, when a battery in discharged state is connected to the circuit, and if the charging current exceeds 4A, transistor T1 conducts to forward bias transistor T3 and transistor T2, in turn, stops conducting, which results in reduced field current of the generator. The net effect is that the output current through the armature and resistor R5 is reduced to maintain the output current from the generator below 4 amperes.

Key-switch operation. Referring back to Fig. 2, when we shift the key switch to 'on' position, the warning bulb glows to indicate that the engine is stationary. One terminal of the warning bulb is connected to the battery via 'on' position of the key switch and the other terminal is connected to the armature (point 'A'), which is grounded through commutator brushes.

The switch motion from 'on' to 'start' position works against the tension of a spring inside the key-switch. After the engine starts and you release the key switch, it automatically comes back and rests at 'on' position. With the engine running, the armature terminal 'A' builds up a voltage of around 14V DC and as such the bulb stops glowing as the current through the bulb reduces considerably.

The key switch works like the ignition key switch of your car. The warning bulb also works the same way as the battery indicator light on the dashboard of your car. The lighting of the battery indicator while the car is running indicates that your car battery is not charging and hence something is wrong. The same goes for the warning bulb on the DG set. In 'on' position of the key switch, the hour-meter starts working. Any other ancillary equipment that you wish to run with the engine could also be connected to the 'on' terminal of the key-switch.

Once the DG set engine is running at the correct speed and the alternator is working, it generates 3-phase, 415V AC at 50 Hz, which is routed to its control panel for monitoring and its further extension to the changeover switch.

Now, if you are satisfied with manual operation of the DG set but wish only to automate the operation of the changeover switch function, it is a rather simple affair. Automatic changeover switches (also called automatic transfer switches (ATS)) are available from a number of electrical switchgear makers.

The AMF system

Fig. 6 shows the block diagram of the proposed AMF system. The system incorporates automatic switching operation of the DG set and its integration with the automatic transfer switch from Havell. Blocks marked 2, 5 and 6 (existing DG set control panel, mains supply via 3-phase isolator and energy meter, and 3-phase load connections via MCCBs, respectively) have already figured in the manual changeover system.

The DG set has been modified by installing an additional solenoid puller along with a contactor (high-current capacity relay) and another identical contactor for electrically starting the engine by making use of the DG set's solenoid-starter combination. Further explanation of the modification is given under the

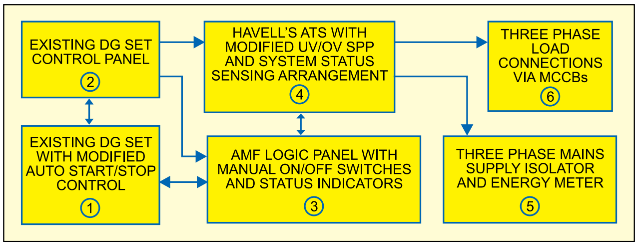


Fig. 6: Block diagram of the proposed AMF system

Three-unit Electromechanical Regulator

Three units control charging. On the left are the cut-out contacts, which connect and disconnect the dynamo armature from the battery. When the output voltage of the generator exceeds 11.8V, the contacts are pulled together and the armature's A terminal is connected via thick wires to the current limiter section. The cut-out section also has a fine wire winding. This winding is connected to ground (also called shunt connected) and provides the magnetic energy to pull the contacts together.

The contacts have a specific air gap and there is a spring trying to pull the contacts open. The spring tension is adjusted to allow the contacts to come together from 11.8 to 13 volts. The thick winding around the outside provides additional pull to the contacts when the current is flowing to the battery to prevent arcing when the voltage output of the dynamo armature is quite close to pull-in voltage.

At the point where the voltage at the armature is below the battery voltage, the current starts flowing from the battery to the armature. This reverse flow of current reverses the polarity of the magnetic field produced by the thick current winding. This magnetic field opposes the field created by the small shunt winding, resulting in a clean release of the contacts.

The centre pole is the current regulator. This section regulates the maximum current that the generator is able to put out without destroying itself. It has a pair of contacts that are normally closed (NC). When the generator voltage starts to flow through the cut-out section, all of the current flows through the current regulator coil.

When the current exceeds a predetermined level (8 to 10 amperes normally), spring tension on the contacts allows the contacts to break. When the contacts open, it removes the hard ground on the dynamo's field (F) terminal. Now, only a parallel path for the field winding to ground is available via a resistor, which causes a reduced-current ground path for the field winding. This reduces the output of the generator.

When the generator output drops, the spring pulls the current contacts back together and bypasses the resistor to ground. The generator again runs to provide the full output and the cycle repeats. If the load is too high, the contacts will be continuously vibrating to limit the current to the preset level. This allows the charging current to be limited to the maximum safe limit.

On extreme right is the third unit forming the voltage control section. It consists of a pair of NC contacts connected in series with the current control contacts to ground and to the field (F) terminal. Under these contacts is a coil of very fine wire wound around a metal pole piece, as the coils on the other two units are. The air gap and the spring tension on these terminals are adjusted to control the voltage output of the dynamo armature from 14 to 14.5 volts.

Since this coil is connected in parallel across the armature terminal to ground, its magnetic field is directly proportional to the armature output voltage. When the voltage reaches the preset level, the contacts break to open the direct ground path for the field current and leave the resistor across the F terminal to ground. As a result, the dynamo armature output voltage drops. The contacts close and the full dynamo armature output becomes available again. It works exactly like the current section, except that it responds only to the voltage output.

There is an additional resistor between the F terminal the armature contact of the cut-out to provide a damping effect when the control contacts open and reduce the arcing of the contacts. It plays no part in the 'controlling' operation of the regulator. The relay contacts are made of tungsten for long life.

description of the modified wiring diagram of the DG set.

Block 3 contains the main logic circuitry for controlling the start/stop of the DG set by making use of sense signals picked up from the DG set as well as from block 4. In addition, it includes audio/visual status and warning indicators, which prompt the operator's intervention during emergency/malfunctioning of equipment. Block 3 also allows you to manually start/stop the DG set, if required.

Block 4 shows use of the industry-standard automatic transfer switch. We've used Havell's ATS due to its relative merits for developing this AMF system. Certain additional circuitry has been incorporated for monitoring both the mains and the DG set supply sources for single-phasing, phase reversal, and under- and over-voltage conditions before permitting changeover of the supply source. The additional circuitry also senses various operations such as tripping of mains and its resumption, as well as the mode of operation of the ATS (auto or manual). These status signals serve as sense signals for the AMF logic panel (block 3) in starting and stopping the DG set appropriately.

The components used for automating the system are detailed below.

Havell's automatic transfer switch

Havell's automatic transfer switch used for this AMF system comprises four symmetrical poles coupled to the main operating mechanism. The switching mechanism is 'quick make, quick break' type. A brief description of its contact mechanism in association with the relay panel (supplied as essential part of the ATS) is given below.

***Contact mechanism** (Fig. 7(a)).* Each pole has two independent sets of moving-contact assemblies for main and standby supply and one fixed-contact assembly for the common outgoing load terminals. Cams, when rotated by the main operating mechanism, mechanically operate the moving-contact assemblies.

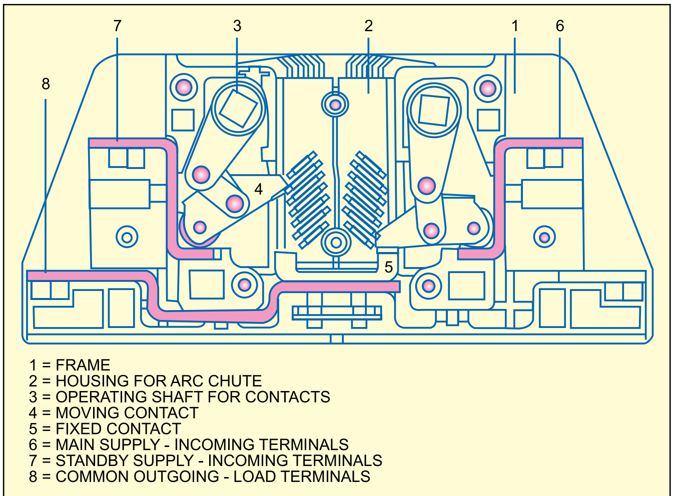
Moving contacts make onto fixed contacts under constant pressure with the back-up spring. Main contacts are made of silver-tungsten to ensure anti-weld characteristics. The Arc Chute plates, placed in the path of contacts, quench the arc and thereby enhance the life of contacts.

The main mechanism independently actuates two sets of cam linkages, which, in turn, operate the two independent moving-contact assemblies.

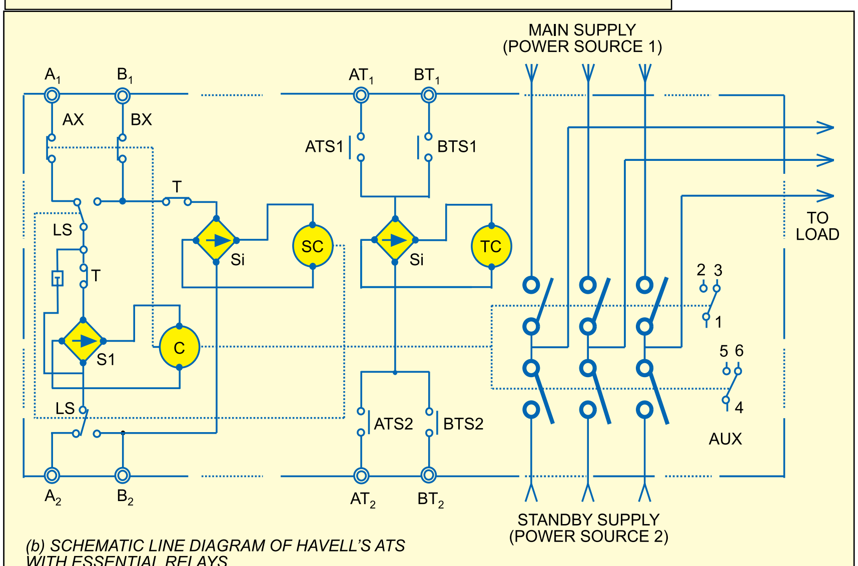
Fig. 7(b) shows the line diagram of Havell's ATS with essential relays. The contact closing command is effected through solenoid closing coil C supplied with 230V AC. The operating mechanism always responds by closing onto the mains supply side and not to the standby supply side when both supplies are present. Tripping coil TC, when energised, brings the automatic transfer switch to off/neutral position. Closing onto the standby supply side is achieved through selective coil SC. The energisation of selective coil SC disengages the main mechanism and prevents closing onto the mains supply side. The solenoid coil can then close the second set of moving contacts onto the standby supply.

The moving contact mechanisms of mains and standby supplies are inherently mechanically interlocked through a double-throw arrangement that ensures that at no point of time the two supplies are paralleled.

During automatic switch operation, the closure of its contacts towards mains or standby side and tripping of the switch to neutral state are effected by certain mechanically-operated contacts as well as relay-operated contacts. All



(a) CONTACT MECHANISM OF HAVELL'S ATS



(b) SCHEMATIC LINE DIAGRAM OF HAVELL'S ATS WITH ESSENTIAL RELAYS

Fig. 7: Contact mechanism of Havell's ATS (above) and schematic line diagram of Havell's ATS with essential relays (below)

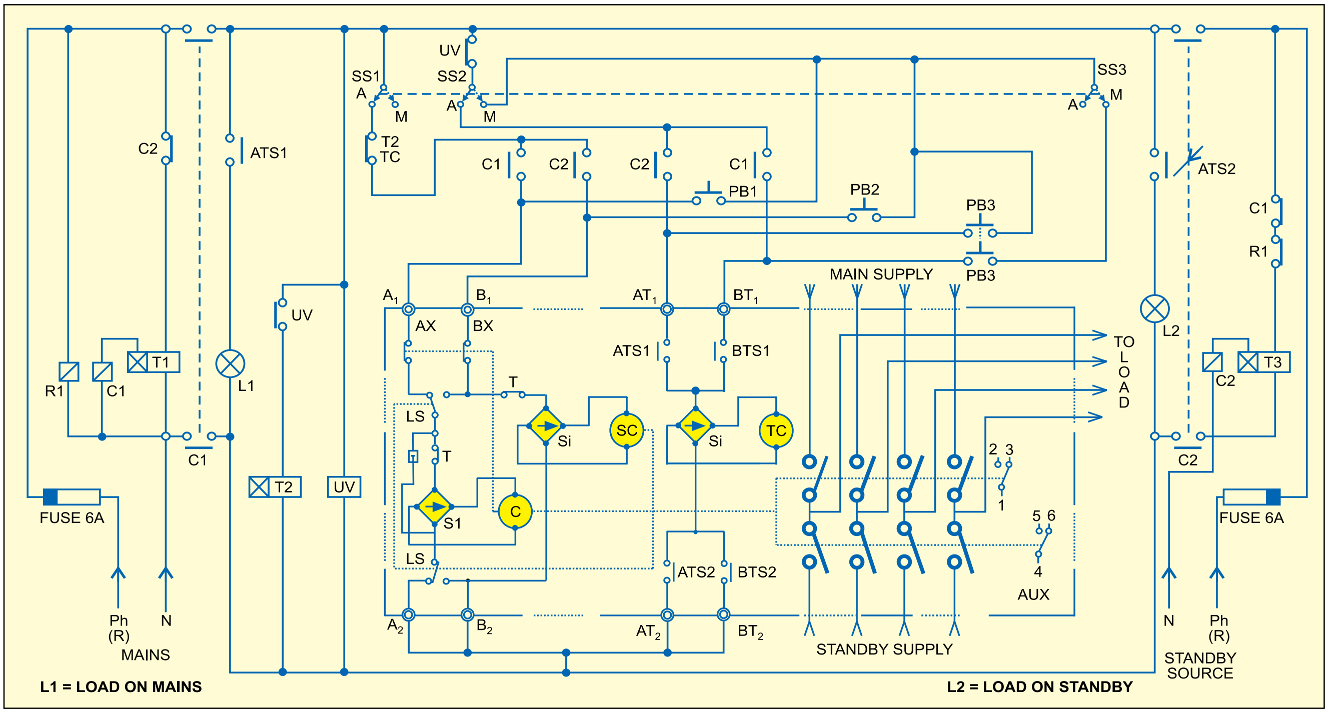


Fig. 8: Line diagram of Havell's integrated ATS

relays/coils operate off 230V AC. For transfer of load onto mains or standby side, 230V AC is applied between terminals A1and A2, or B1 and B2, respectively. For tripping of mains or standby, the 230V AC is applied between terminals AT1 and AT2, or BT1 and BT2, respectively.

Function of some of the relays for operation of the ATS has already been given under the description of its contact mechanism. However, operation of all contacts/relays (coils) used within the ATS, as shown in Fig. 7(b), is summarised below:

1. Auxiliary contacts AX and BX: When ATS switch is in off (tripped/neutral) state, auxiliary mechanical contacts AX and BX are in closed state. When the ATS energises via closing coil C towards mains or standby side by operation of selective coil SC, in association with closing relay C, the respective auxiliary contacts break and the supply to closing coil is cut off.

2. ATS1 and ATS2, and BTS1 and BTS2: These two pairs of mechanical contacts for mains and standby sources, respectively, close when the respective supply has been switched on via the ATS. The application of 230V AC between the affected terminals AT1 and AT2, or BT1 and BT2, will energise trip coil TC to bring the switch to neutral position.

3. TC: Trip coil, when energised, trips the switch to neutral position.

4. SC: Selective coil, when energised, disengages the main mechanism and prevents closing towards the mains supply side by pulling limit switches marked LS (Fig. 7) towards B1 and B2 contacts. SC coil is used along with closing coil C to close towards the standby side.

Emergency operation of ATS. In an emergency, the ATS can be operated manually, as an off-load switch only, as follows:

1. Closing onto mains supply: A manual handle rotates the operating shaft by 45° in anticlockwise direction to achieve closure under off-load conditions.

2. Closing onto standby supply: Closure onto the standby supply side is achieved when 'Selective' mode (through selective command hole) is continuously pressed and the manual handle rotates the operating shaft by 45° in anticlockwise direction.

3. Tripping: Tripping can be achieved manually by pressing 'Trip' button momentarily.

Caution. Before the emergency operation, isolate the load from the ATS.

Integrated ATS operation. The Havell's ATS now comes as an integrated unit. A line diagram of the integrated unit is shown in Fig. 8. Apart from the components shown in Fig. 7(b), it comprises selector switch, pushbuttons, indicator lamps and relays including timers.

The mode-selector switch is a 3-way, double-changeover switch. The three poles in the circuit are marked as SS1, SS2 and SS3. The auto position is marked 'A,' while manual position is marked 'M.' Pushbutton switches PB1, PB2 and PB3 are used for selection of mains and standby (DG set) supplies and tripping of the selected source (mains/standby), respectively, in manual mode of operation. Pushbutton PB3 has two mechanically interlinked sections as shown in the figure. The controlling voltage is derived from Red phase and Neutral of the respective supply sources connected to the circuit via fuses rated at 6 amperes each.

The ATS operates in auto and manual modes as follows:

1. Auto mode. For operation in auto mode, the switch is to be kept in auto (A) position. Let's assume that initially the ATS is in neutral (tripped) position and mains supply is available. Relay R1 energises almost instantaneously, opening its NC contacts marked R1 to ensure that even if standby supply becomes available subsequently, it will not be able to reach timer T3 and contactor C2 (which ultimately controls the SBY source selection). Even if both supplies (mains and standby) become available simultaneously, the standby supply will be cut off from reaching contactor C2 (because of the delay introduced by timer T3), while no timer comes in the path of relay R1.

The mains' red phase becomes available to timer T1, which connects the phase to contactor C1 after the preset delay. Once contactor C1 energises and closes its two contacts, it extends mains' red phase and neutral to A1 and A2 points of the ATS assembly (shown within dotted lines). The phase supply is routed to A1 terminal via SS1 and NC contact T2 of UV (under-voltage relay) initiated timer, which remains closed unless it encounters prolonged under-voltage condition. This sequence ensures switching of load to mains as explained earlier. The mains indicator bulb lights via ATS-1 contact of the ATS. As an additional safety, the NC contact C1 in series with R1 contact also opens during energisation of C1 contactor to break the path for standby supply.

When mains is not available (trips), relay R1 and contactor C1 de-energise. Now, if standby supply from the DG set is made available, its red phase reaches timer T3 via closed R1 and C1 contacts and, after preset delay of T3, contactor C2 energises to open the NC contact in the path of mains' red-phase supply to timer T1. Switching of the standby supply's red phase to control the ATS operation is feasible only after the delay introduced by timer T3.

In case mains resumes before T3's delay period is over, R1 will energise to open the control circuit for standby supply and mains will become available to the load.

However, if mains does not resume within the delay period of timer T3, C2 will energise and it will trip mains from the load via SS2 section of the selector switch (and AT1 and AT2 contacts) before closing towards standby side due to energisation of B1 and B2 contacts via SS1 section of the selector switch and closed contacts of T2. The load is switched to standby supply and L2 indicator bulb glows.

Now, if mains resumes, it will open the path for C2 due to energisation of R1. Once C2 de-energises, C1 will energise via T1. Now, via SS2 section of the mode switch and C1 contacts, the ATS will trip via BT1 and BT2 contacts before switching the load to mains source once again.

2. Manual mode. For manual-mode operation, the selector switch is to be kept in manual (M) position. It is advisable to press the trip button before changing from one source to another in manual mode.

In manual mode, both pairs of trip contacts (AT1 and AT2, and BT1 and BT2) are paralleled via SS3 section of the mode switch when trip button (PB3) is pressed. Pressing of trip button ensures that whatever source is presently connected to the load, it trips the ATS and brings it to neutral position. The red phase of any of the available supplies (mains when both supplies are available) can be used to switch the load towards mains (using pushbutton PB1) or standby supply (using PB2). The automatic operation of the ATS is inhibited by SS1 and SS2 sections of the mode-selector switch. Before changing over the source again, press trip switch PB3 before pressing PB1 or PB2.

We had explained the working of the manual changeover system/ components as well as the components utilised for the automatic changeover system. Next section covers the modifications effected in the Havell's automatic transfer switch (ATS) and the Kirloskar 62.5kVA DG set, as well as design of the logic control circuitry for automating the operation of the changeover system.

Modifications in the ATS

Havell's ATS does not monitor all the three phases for under-voltage protection, nor does it have over-voltage or single-phasing or phase-sequence-change prevention arrangement. We have therefore used an industry-standard Minilec make SPP relay (VMR D2) that incorporates all these protections. Its normally-opened (N/O) contacts energise only when all the conditions are satisfied.

We have used a VMR D2 relay for each of the two 3-phase supply sources, i.e., mains supply as well as the DG set supply. The red-phase input from the respective sources is extended to the fuse and neutral point of each control supply to the Havell's ATS when the conditions are fulfilled. The under-voltage limits (80 to 95 per cent) and over-voltage limits (105 to 120 per cent) of the auxiliary supply are adjustable via screwdriver controls.

We have used a 4-way (three N/O and one N/C contacts), 9A rated contactor in conjunction with VMR D2 relays (one each for mains and standby source) to detect the healthy supply status of the available supplies to the logic control panel and to extend the red phase of supplies to Havell's ATS. The connections to VMR D2 relay for 415V AC 3-phase (with 415V AC auxiliary supply), and associated 4-way contactor, are made as under:

1. 415V AC 3-phase supply is connected to terminals marked 1, 2 and 3 (in top row).
2. Auxiliary voltage terminals 7 and 8 (middle row) are connected to any two phases (we used 'R' and 'Y' phases).
3. N/O terminals 13 and 14 (bottom row) are used for energising the 4-way (three N/O and one N/C) contactor. The contacts close only when the 3-phase supply is healthy.
4. Red phase and Neutral of the respective supplies are extended via two N/O contacts to Havell's ATS for control.
5. The remaining two contacts (one N/O and one N/C) are used for conveying the healthy supply status of

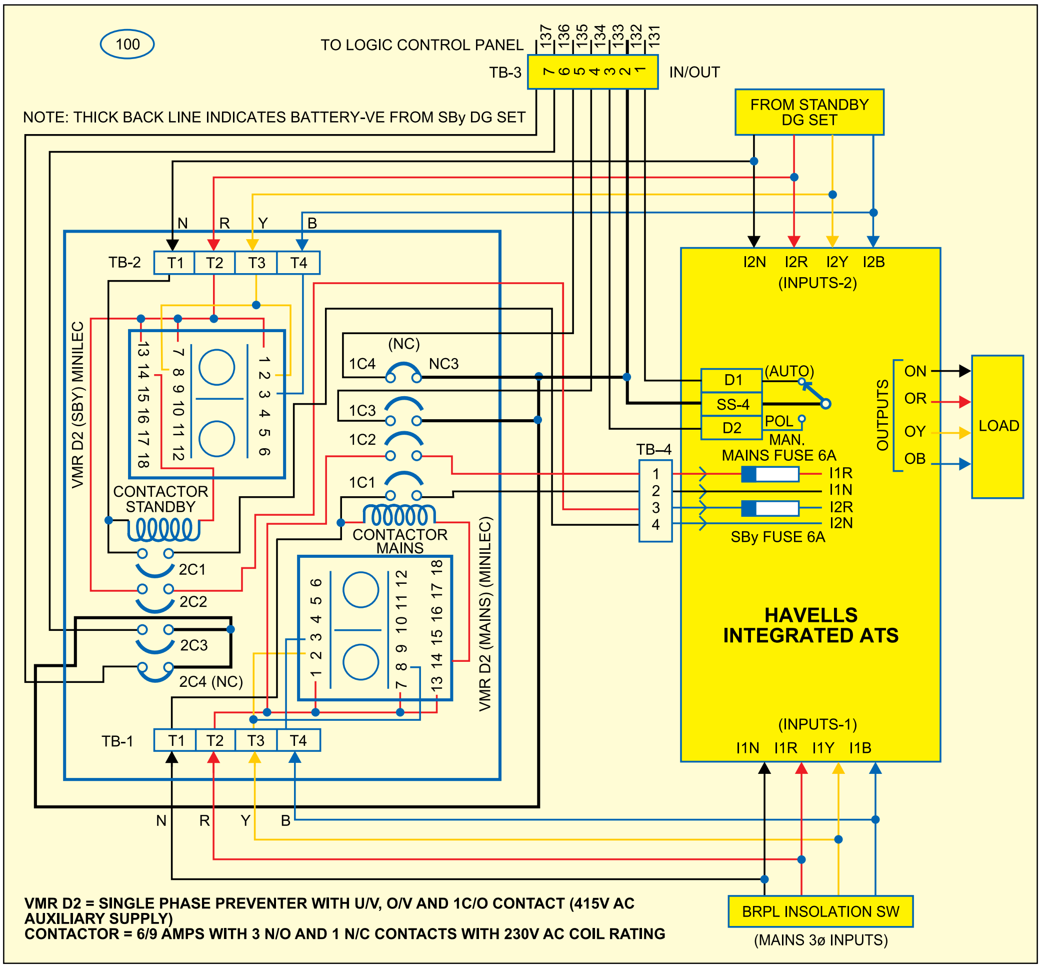


Fig. 9: Havell's integrated ATS showing modifications

the source to the logic control panel.

Further, we have replaced the 3-way, double-changeover mode-selector rotary switch with a similar 4-way, double-change-over rotary switch (Kaycee make 4F46D). The fourth section (SS4) has been used to convey the selected mode information to the logic control panel.

The Havell's integrated ATS with the modified wiring is shown in Fig. 9.

Modifications in DG set

Fig. 10 shows the modified wiring diagram of the standby DG set.

For automating the start, stop and run operations of the DG set, we need to sense its present operational status. Two signals are used for knowing the status of the DG set. These are 230V AC alternator output (across R-phase and Neutral) and dynamo-induced voltage of about +14.5V DC. Both these voltages become available after the DG set is running. (***Note:*** For +14.5V to be available, +12V from the DG set battery needs to be extended to 'On' terminal of the key-operated start switch.) A relay in the logic panel was used to extend the +12V supply to 'Run' terminal.

For starting the DG set, we have to switch +12V to the solenoid (forming inbuilt part of the starter) of the starter using a relay with contact rating in excess of 20 amperes. Also, for stopping the DG set, we use a similar relay for energising a solenoid puller.

The solenoid puller (purchased from the local market in Delhi) was secured to rails on which the DG set rests. Its free-moving central rod end was attached to the lever (used for manually stopping the engine) using a thin wire rope, similar to the one used in scooters for clutch/gear operation. As the solenoid arm had no tension, a spring of suitable tension and length was used so that it returned to its original position along with the stop lever once the solenoid was de-energised.

The battery supply and 'IND' terminal of the dynamo are extended to the indigenously designed logic control panel via TB1, while for energising the 'stop' and 'start' relays, and for extending +12V to 'Run' terminal, pin 5 of TB1 is used. The AC sample (R-phase and neutral) from the DG set alternator is extended to the logic control panel via pins 1 and 2 of TB2.

A total of eight lines carrying DC and AC power, and sense and control signals are routed from the DG set to the logic control panel, and another seven lines carrying sense signals are routed from the ATS cubicle to the logic control panel. Fig. 11 shows the interconnection diagram. The arrows indicate the direction of signals.

It is desirable that each wire-end bears proper marking, so that after a disconnection for any fault rectification, the wires are connected back to their original points. For this purpose, numbered plastic ferrules are available from electrical switchgear dealers, which can be inserted in the cable ends to mark the wire numbers. The wiring conventions proposed in Fig. 11 can be used for identification. Use of multicolour leads (with resistor-type colour code) can further eliminate the risk of wrong connections during/after any servicing.

Logic control panel

A summary of signals carried from/to the logic control panel tag blocks (TBs) to/from the DG set and the ATS cubicle, along with their direction with respect to the logic control panel, is given in Table above. These signals are used to control the start and stop logic for the DG set.

Specifications. The conditions governing the automatic start and stop operation of the DG set and the related timings need to be specified for designing the logic control circuitry. Some of the conditions and timing requirements will vary for individual systems depending on the power rating, battery voltage, and built-in facilities of the DG set. The system design must also take into account the operational requirements/constraints of the system, including whether the DG set is required to feed the load on 24-hour basis (in case of mains failure) or from dawn to dusk, etc. The auto-start and stop logic used by us for our specific system is explained below.

Auto-start logic for the DG set. For the DG set to start, the conditions required are:

1. The mode-selector switch is in 'auto' mode.
2. The DG set is not already running.
3. A transition from 'mains available' to 'mains not-available' has been detected.
4. Mains (healthy) is not available even after 3-second wait, while conditions 1 and 2 are still applicable.

Once conditions 1 through 4 have been satisfied and the engine has gained about 80 per cent speed (as evidenced by the dynamo/alternator output), the starter can be deactivated.

Auto-stop logic for the DG set. For initiating the stop action for the DG set, the following conditions must be met:

1. The mode selector switch is in 'auto' mode.
2. The DG set is running.
3. A transition from 'mains not available' to 'mains available' has been detected.
4. Mains (healthy) is available even after 30-second wait, while conditions 1 and 2 are still applicable. The 30-second is off-load cooling period for the DG set. ***(Note:*** A higher cooling period must be taken for engines of higher rating.)

Once conditions 1 through 4 have been satisfied, the engine stopping action is initiated and unless the engine comes to a dead stop, the controlling solenoid should not be released; else, the engine will tend to restart because of inertia.

Engine-cranking logic. This logic functions in association with the auto-start logic for the DG set.

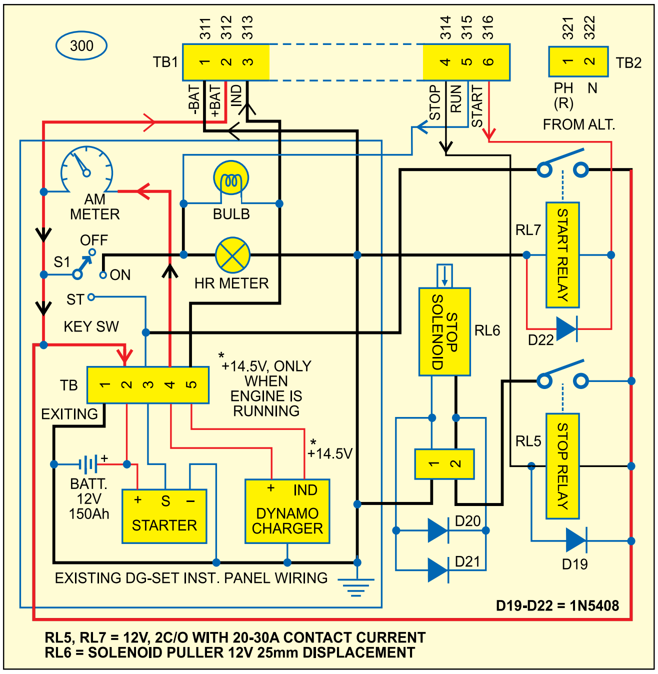


Fig. 10: Modified wiring diagram of the standby DG set

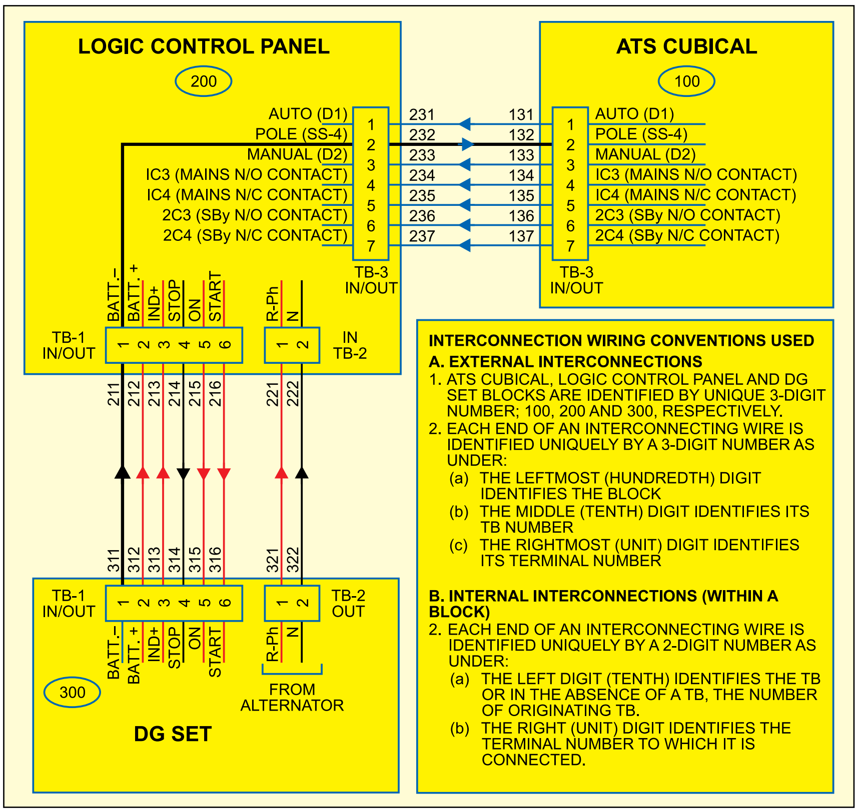


Fig. 11: Interconnections between the logic control panel and the DG set as well as the ATS cubical

Once conditions governing the 'DG set auto-start logic' have been satisfied, and continue to remain satisfied, engine-cranking (starting) is attempted for around twelve seconds. This period is practically adequate for the engine to pick up the speed without excessive draining of the battery.

During winter when the engine remains idle during the whole of night, the

Signals Carried to and from the Logic Control Panel

TB Tag No.	Signal	Direction	Description
TB-1 Tag No.			TB-1 is used for carrying the DC supply and control signals.
1	Bat. -	In	It carries BAT- (Gnd.) from the battery in the DG set.
2	Bat.+	In	It carries +12V from the battery in the DG set.
3	+IND.	In	This wire carries +14.5V generated by the dynamo.
4	Stop	Out	This output is active-low (Gnd) for energising 'Stop' relay RL5 in the DG set (see Fig. 11).
5	On	Out	This output is active-high (+12V). Once the engine starts, it extends +12V to 'On' terminal of the keyswitch.
6	Start	Out	
TB-2 Tag No.			TB-2 is used for carrying the alternator output (red phase and neutral) sample for initiating activation of 'On' relay RL1, which extends +12V to 'On' point of the keyswitch.
1	R.Ph.	In	With the engine running, it carries the red phase from the alternator to energise relay RL1 in the logic control panel.
2	N	In	This terminal extends neutral from the alternator.
TB-3 Tag No.			TB3 brings in active-low (Gnd) signals (via terminals 1, 3 through 7) from the control cubical under different conditions.
1	Auto	In	BAT- (Gnd) return when the mode-selector switch in the ATS cubical is kept in 'auto' position.
2	Pole	Out	BAT- (Gnd) is extended to the ATS cubical via the pole of mode-selector section SS4.
3	Man.	In	BAT- (Gnd) return when the mode-selector in the ATS cubical is in 'manual' position.
4	C3 (N/O Mains)	In	BAT- (Gnd) return when (healthy) mains is available.
5	C4 (N/C Mains)	In	BAT- (Gnd) return when (healthy) mains is not available.
6	C3 (N/O SBy)	In	BAT- (Gnd) return when (healthy) SBy is available.
7	C4 (N/C SBy)	In	BAT-(Gnd) return when (healthy) Sby is not available.

viscosity of lube oil is high, which puts a higher load on the starter and as such the starter may not be able to start the engine at first attempt. Under these circumstances, it is advisable to start the engine manually (after switching off the logic control panel), two/three times so that the starter is able to function smoothly in auto position, in one attempt itself.

If the engine fails to start in the first attempt (of 12 seconds), it waits for 70 seconds before making the next attempt. This period is essential for the battery to accumulate charge for subsequent cranking attempts. The maximum number of cranking attempts can be preset (between two and five) by the operator. A higher number of cranking attempts indicates that the high-viscosity lube oil has been used, the battery terminals/leads to the starter need cleaning/tightening, the starter pinion is not meshing properly with the engine flywheel gear, or the starter itself needs servicing. If the engine fails to start within the preset attempts, audio-visual warning is activated.

Logic control circuit

Apart from implementing the above-mentioned logic, the logic control panel performs quite a few additional functions as well, which will become clear when we go through its circuit details. The schematic diagram of the logic control circuit is shown in Fig. 12.

The connections to/from the DG set are terminated on TB-1 (shown split in two sections) and TB-2, while TB-3 is used for terminating connections to/from the ATS cubicle. The description of the signals on these TBs is given in the table. The ground (battery negative) connection from pin 1 of TB-1 is extended to the modified ATS circuit via pin 2 of TB-3. This ground connection is returned via other pins of TB-2 to indicate the state of mode switch and mains and standby supply sources. The status is displayed through LEDs (LED1 through LED6). Three of these six signals (auto mode 'on,' mains 'on' and mains 'off') are used for logic control.

Detection of the DG set engine status. For detecting the 'on/running' status of the DG set, initially the AC output from its alternator is monitored by the circuit built around MCT2E optocoupler (IC15). The value of resistors R38 (33 kilo-ohms, 0.5W) and R39 (390 ohms, 0.25W) is selected to develop around 3.8V peak across R39 and around 2.5V across capacitor C36 after bridge rectifier BR1.

Considering a voltage drop of 1.25V across the LED of the optocoupler, resistor R36 (120 ohms) is used to limit the current to about 10 mA through the optocoupler LED. The collector of the optocoupler is in low state with the engine/alternator running.

The output of the alternator serves as one of the two inputs to NAND gate IC2B, and is also used for energising 'Run' relay RL1 via NAND gate IC2D (wired as an inverter) and driver ULN2004A (IC8).

On energisation, RL1 contacts extend +12V to 'on' contact of the keyswitch via pin 5 of TB-1. As a result, the hour meter of the DG set starts running and also the dynamo output becomes available for charging the battery of the DG set. The dynamo IND terminal brought to pin 3 of TB-1 goes high (about +14.5V). The output from pin 3 of TB-1 is inverted by NAND gate IC2A and extended to NAND gate IC2B, which acts as a NOR gate (negative logic). Thus when the engine is running, output pin 4 of IC2B is high. Else, it is low.

Two alternate signals have been

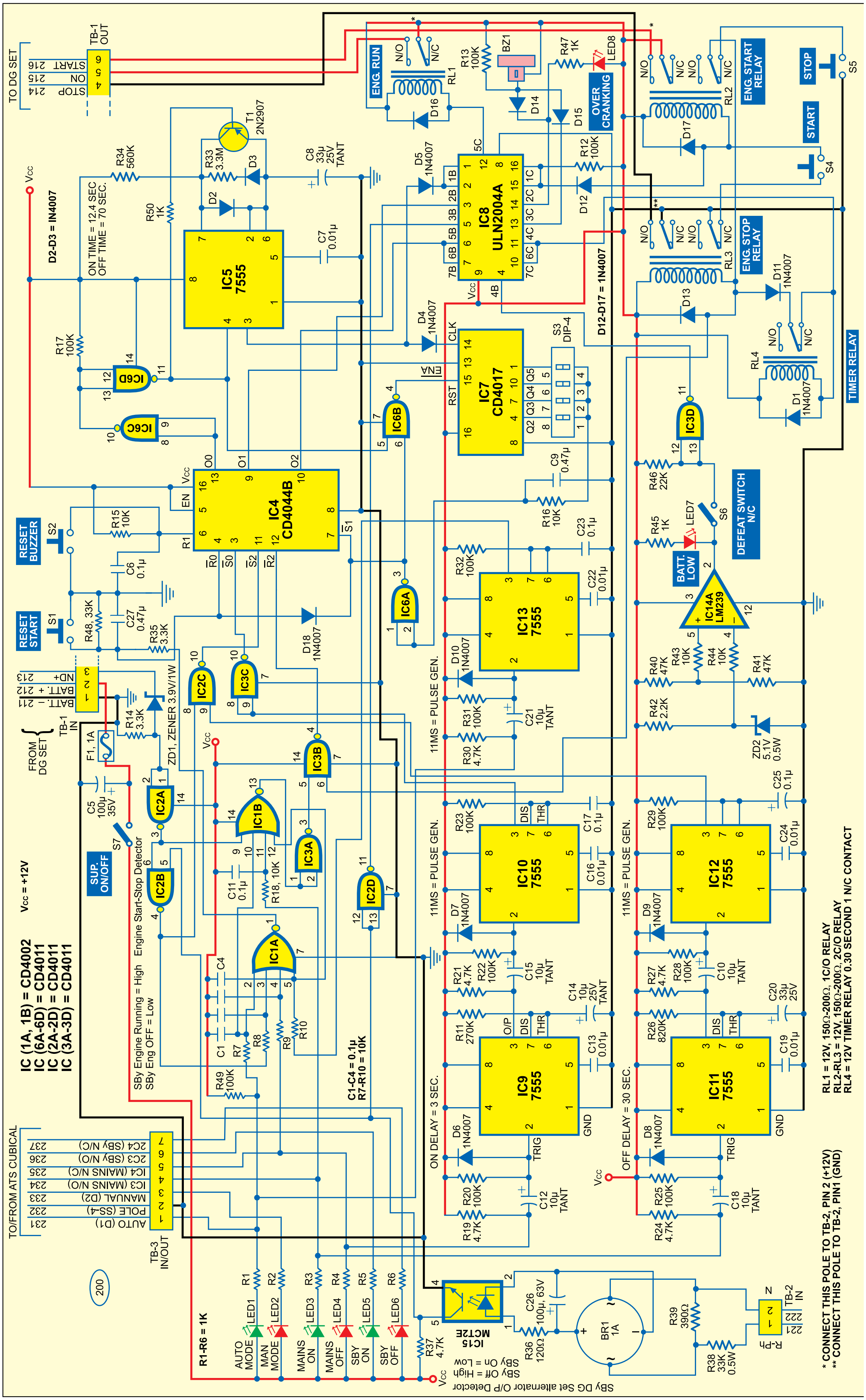


Fig. 12: The logic control circuit

used to indicate the status of the DG set so that if one of the two signals (alternator output or dynamo output) gets disconnected, the other one is available. The output of IC2B is used as the sense signal for 4-input NOR gate IC2A and as a gate (enable signal) for NAND gate IC2C.

IC CD4044B. Quad RS latch CD4044 (IC4) with 3-state outputs has been employed as the core IC for developing the engine start and stop logic. Therefore, before we examine implementation of the logic, let us have a look at the functional block diagram and truth table of CD4044B as shown in Fig. 13. We observe that with Eo pin tied to H (Vcc), the 'on' output will follow:

1. High logic state of Rn only when Sn input pin is held low. Subsequently, even if Sn input goes high, the output 'on' will continue to stay high (latched).

2. Low state of Rn input irrespective of Sn input. This implies that Rn input can be used to reset the 'on' output.

Implementation of the engine start logic. With mode-selector switch in 'auto' position, and mains tripping, we have all the four inputs of NOR gate IC1A low, since:

1. Pin 1 of TB-3 is low when mode switch is in 'auto' position. This is connected to pin 2 of IC1A.

2. When the DG set is not running, the output of NAND gate IC2B is low (since its both inputs are high). This is connected to pin 3 of IC1A.

3. Pin 5 of TB-3 goes from high (when mains is available) to low (when mains becomes unavailable). This is connected to pin 4 of IC1A.

4. The output of monostable IC3 is low in steady state. This is connected to pin 5 of IC1A.

Thus the output of IC1A at pin 1 goes high and the same is connected to R0 input pin 4 of CD4044B (IC4) via resistor R35. The resistor-capacitor combinations at the inputs of IC1A absorb any transients.

Transition detection and delay circuit. As stated earlier, pin 5 of TB-3 undergoes a high-to-low-to-high transition. This transition is detected by a differentiating network comprising capacitor C12, resistor R20 and diode D6. Resistor R19 is used for pulling pin 1 of TB-3 high before transition.

The detected negative-going pulse is coupled to trigger pin 2 of monostable IC9 employing CMOS timer IC 7555, which produces a 3-second wide pulse at its output pin 3. The pulse width can be changed by varying either the value of the resistor between Vcc and pin 7/6 or the capacitor between pin 7/6 and ground as per the following relationship:

Time (seconds) = 1.1R (ohms) × C (Farads).

The trailing end of this pulse triggers the next monostable (IC10), which is wired the same way as IC9 but produces a much shorter (10-12ms) low-to-high going pulse at its output. This pulse is inverted by NAND gate IC3C before application to S0 input (pin 3) of CD4044 (IC4). This results in transferring and latching of the high logic state of R0 (pin 4) to O0 output (pin 13), provided pin 4 continues to be held high even after the 3-second delay. That will be true as long as all the inputs of IC1A remain low, fulfilling the engine-start logic conditions.

Engine start circuit. The engine start circuit comprises IC5 through IC8, start control relay RL3 and high-current start relay RL7 (refer Fig. 10) in the DG set, and associated components. As soon as O0 output (pin 13) of IC4 is latched to high state, the same is buffered by IC6C and IC6D NAND gates (before application to reset pin 4 of IC5), one of the two inputs of NAND gate IC6B as well as the base of pnp switching transistor T1 (2N2907) via 1-kilo-ohm resistor R50.

CMOS timer IC5 is configured as an astable flip-flop controlled by the logic state of its reset pin 4. Its 'on' period is 12.4 seconds and 'off' period is 73 seconds. ('On' period=$0.67(560\times10^{3}\times33\times10^{-6})$ sec.≈12.4 sec. and 'off' period=$0.67\ (3.3\times10^{6}\times33\times10^{-6})$ sec.≈73 sec.) For as long as reset pin 4 is held high, transistor T1 remains cut-off, but once the reset pin goes low, timing capacitor C8 discharges rapidly to keep

PARTS LIST

Semiconductors:		
IC1	-	CD4002 dual four-input NOR gate
IC2, IC3, IC6	-	CD4011 quad two-input NAND gate
IC4	-	CD4044 quad NAND R-S latch
IC5, IC9-IC13	-	7555 timer
IC7	-	CD4017 decade counter
IC8	-	ULN2004A relay driver
IC14	-	LM239 quad differential comparator
IC15	-	MCT2E optocoupler
T1	-	2N2907 pnp switching transistor
D1-D18	-	1N4007 rectifier diode,1A
D19-D22	-	1N5408 rectifier diode, 3A
BR1	-	1A bridge rectifier
LED1-LED8	-	Red/green LEDs
ZD1	-	3.9V, 1W zener diode
ZD2	-	5.1V, 0.5W zener diode
Resistors (all ¼-watt, ±5% carbon):		
R1-R6, R45, R47, R50	-	1-kilo-ohm
R7-R10, R15, R16, R18, R43, R44	-	10-kilo-ohm
R11	-	270-kilo-ohm
R12, R13, R17, R20, R22, R23, R25, R28, R29, R31, R32, R49	-	100-kilo-ohm
R14, R35	-	3.3-kilo-ohm
R19, R21, R24, R27, R30, R37	-	4.7-kilo-ohm
R26	-	820-kilo-ohm
R33	-	3.3-mega-ohm
R34	-	560-kilo-ohm
R36	-	120-ohm
R38	-	33-kilo-ohm, 0.5W
R39	-	390-ohm
R40, R41	-	47-kilo-ohm
R42	-	2.2-kilo-ohm
R46	-	22-kilo-ohm
R48	-	33-kilo-ohm
Capacitors:		
C1-C4, C6, C11, C17, C23, C25	-	0.1µF ceramic disk
C5	-	100µF, 35V electrolytic
C7, C13, C16, C19, C22, C24	-	0.01µF ceramic disk
C8, C20	-	33µF, 25V tantalum
C9, C27	-	0.47µF polyester
C10, C12, C14, C15, C18, C21	-	10µF, 25V tantalum
C26	-	100µF, 63V electrolytic
Miscellaneous:		
ATS	-	Havell's 100A ATS with enclosure (220V AC tripping)
VMRD2	-	Minilec VMR D2 single-phase preventer with U/V, O/V and 1C/O contacts (415V AC auxiliary supply)
Contactor	-	6/9A with 3 N/O and 1 N/C contacts, 230V AC coil rating
S1, S2	-	Push-to-on tactile switches
S3	-	4-way DIP switch
S4, S5	-	Push-to-on switch for manual start and stop operations (BCH/Vaishno brand)
S6, S7	-	Toggle switch
BZ1	-	12V piezobuzzer
RL1	-	12V,150- to 200-ohm, 1C/O relay (OEN R series/PLA MPC series or equivalent)
RL2, RL3	-	12V, 150- to 200-ohm, 2C/O relay (OEN R series/PLA MPC series or equivalent)
RL4	-	12V, 0-30 sec. timer relay with N/C contacts
RL5, RL7	-	12V, 2C/O, 20-30A contact rated relay
RL6	-	12V, 25mm displacement solenoid puller
	-	Tag blocks, ferrules, spade/eye ends, connectors, multicolour cable, enclosure for logic control circuit, etc

the timer in complete reset state. In the absence of transistor T1, the output at its pin 3 diminishes very slowly inspite of holding the reset pin low.

The output from pin 3 of astable IC5 is coupled to input pins 1 and 2 of high-current Darlington driver array ULN2804 (IC8) as well as clock pin 14 of decade counter CD4017 (IC7) through isolating diodes D4 and D5, respectively.

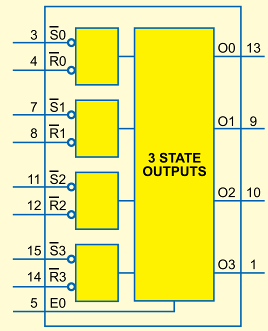
During positive clock period of IC4, output pins 15 and 16 of ULN2004A (shorted for augmenting the driving current capacity of IC8 output) energise 'start' relay RL3 to extend +12V battery supply to high-current relay RL7 (in the DG set) via pin 6 of TB-1 to energise the starter. At the same time, the high output of CD4017 (IC7) shifts from Q0 (pin 3) to Q1 (pin 2).

If the DG set starts within 12.4 seconds, it will cause pin 3 of NOR gate IC1A to go high. This, in turn, will cause output pin 1 of the IC to go low to reset O0 output of CD4044 (IC4). The low output at pin 13 of IC4 will reset the astable flip-flop as well as decade counter IC7 via NAND gate IC6B. Also, timer capacitor C8 will quickly discharge into pin 7 of IC4 because of the conduction of transistor T1.

In case the engine doesn't start within the first 12.4 seconds, reset pin 4 of astable flip-flop IC5 stays high, while timing capacitor C8 starts slowly discharging through 3.3-mega-ohm resistor R33 into pin 7 of IC4.

After 73 seconds, output pin 3 of IC4 again goes high for another 12.4 seconds, provided the DIP switch part connected to pin 4 (Q2) of IC7 is not closed. If the switch is closed, the high output at pin 4 of IC7, after passing through the pulse stretcher network comprising resistor R16 and capacitor C9 and inversion by NAND gate IC6A, will cause pin 4 (R0 input) of IC4 to reset its output pin 13 and thus the astable flip-flop (IC5) as well as decade counter IC7 will also be reset.

The negative pulse at the output of NAND IC3A is also directly connected to S1 input (pin 7) of IC4, while its R1 (pin 6) is pulled high through resistor R15. This causes latching of O1 output (pin 9) of IC4 to high state and, in turn, activation of cranking indicator LED8 as well as buzzer BZ1 via ULN2004A. Once the operator has noted the warning, he can reset the LED and the buzzer by pressing 'Reset Buzzer' tactile switch S2, which causes resetting of O1 output (pin 9) to low state.



CD4044B

INPUTS			OUTPUTS On
EO	$\bar{S}$n	$\bar{R}$n	
L	X	X	Z
H	L	H	H
H	X	L	L
H	H	H	LATCHED

NOTES
1. H = HIGH STATE (THE MORE POSITIVE VOLTAGE)
L = LOW STATE (THE LESS POSITIVE VOLTAGE)
X = STATE IMMATERIAL
X = HIGH IMPEDANCE OFF-STATE

Fig. 13: Functional block diagram and truth table of CD4044B

In case you want to allow up to three cranking attempts, you need to flip the third switch of DIP switch S3 to 'on' position. The audio-visual warning will not activate if the engine starts within the preset attempts.

Implementation of the engine stop logic. Quad NOR gate IC1B is used for detecting some of the stop conditions.

The first conditions of start and stop logic are identical, i.e., the mode-selector switch in the ATS cubical must be in 'auto' position. Therefore pin 2 of IC1A is shorted to pin 10 of IC1B.

The second condition is that the DG set is already running. When the DG set is running, pin 3 of TB-1 is at around +14.5 V and hence the output of NAND IC2A at its pin 3 goes low, which is connected to pin 9 of quad NOR gate IC1B.

The third condition is the availability of healthy mains and its transition from 'not-available' to 'available' status. When mains becomes available, pin 2 of TB-3 goes from 'high' to 'low' (mains 'on' LED4 also lights up). This low output is extended to pin 11 of IC1B via R18.

Once these three conditions are satisfied, the output of IC1B goes high. This high output is applied to R2 input (pin 12) of CD4044 (IC4) after ORing it with another input from the timer circuit. The ORing function is realised using NAND gates IC3A and IC3B.

The mains 'off'-to-'on' transition (occurring at pin 2 of TB-3) detection and 30-second delay for allowing the DG set to cool down (off-load running) are accomplished by the edge-detection and delay mono circuit comprising IC11 (7555).

After 30 seconds, the trailing edge of the output of IC11 triggers IC12 to produce an 11ms pulse, which is passed to pin 9 of NAND gate IC3C, while its pin 10 is enabled (gated) by the engine start/stop sensor output of IC3B. Thus S2 input (pin 11) of CD4044 receives a low-going pulse only if the engine is still running. As a result, O2 output of CD4044 is latched high. This high output is applied to pins 6 and 7 (tied together) of ULN2004A and its output pins 10 and 11 go low to energise timer relay RL4 as well as 'stop' control relay RL3 (via NC contacts of timer relay).

The timer is set for 12 to 15 seconds. This time duration is appropriate for bringing the engine to a dead stop. Energisation of RL3 extends ground for activation of high-current 'stop' relay RL5 in the DG set, which, in turn, activates 'stop' solenoid RL6 in the DG set for the set period.

As mentioned earlier, the engine must come to a dead stop before releasing the engine-stop solenoid. For this, we have to ensure that O2 output at pin 10 of IC4 (CD4044) remains latched (to 'high' state) for the preset delay of the timer. Therefore the low output from pins 10 and 11 of ULN2004 (via N/C contacts of timer relay and diode D11) is applied to pin 6 of NAND gate IC3B. As a result, the output of IC3B or R2 input (pin 12) of CD4044 goes high for the preset period of timer relay RL4.

After the set period is over, the N/C contacts of the timer relay open up and Vcc (via the coil of relay RL3) is extended

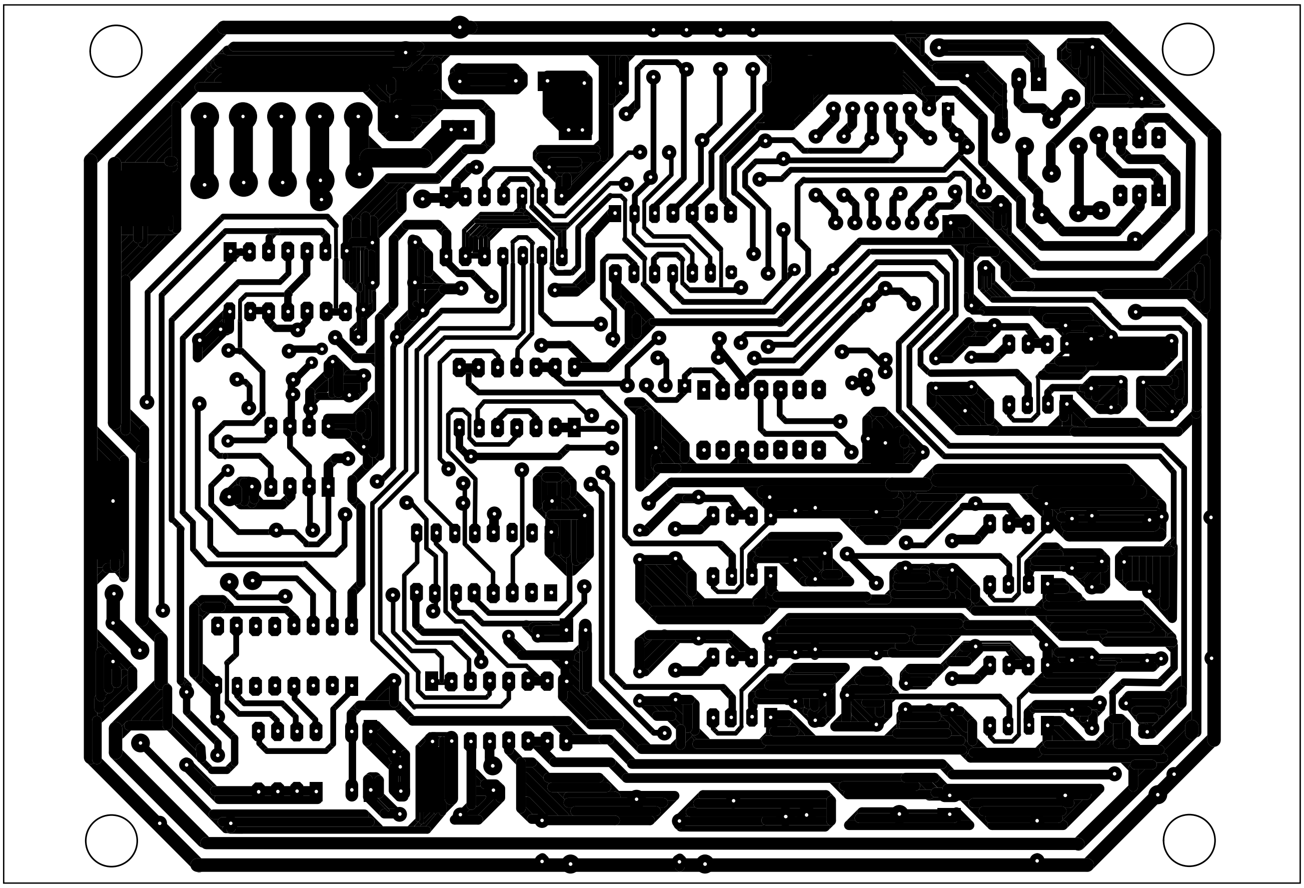


Fig. 14: Single-side, actual-size PCB for the logic control circuit

to pin 6 of IC3B, while pin 5 also goes high since, with the DG set in 'off' condition, pin 9 of quad NOR gate goes high and its output pin 13 goes low. The same output after inversion by NAND gate IC3A is applied to pin 5 of IC3B. As a result, the output of IC3B goes low to reset O2 output of CD4044 and ' engine stop' control signal comes to an end.

Battery-low warning circuit. When the battery voltage falls below 10V, the auto start/stop circuit may not function satisfactorily. It is a sure indication of one or more of the following conditions:

1. Charging circuit is non-functional.
2. The battery is not holding charge due to sulphation or the electrolyte needs to be topped up.
3. Dynamo pulley belt is slipping.
4. The battery has some load when the engine/dynamo is not 'on.'

The warning circuit comprises comparator IC14A (LM239), which compares a 50 per cent sample of the battery voltage against the 5V reference voltage developed across zener ZD2. The output of the comparator is high as long as the battery voltage exceeds 10V.

When the battery voltage falls below 10V, the comparator output goes low to light LED7. Switch S6 is normally kept closed. As a result, when the battery voltage goes below 10V, the output of NAND gate IC3D goes high to sound piezobuzzer BZ1 via ULN2004A and diode D15, which acts as an OR gate here. (In case you need to activate a high-power siren, in place of the buzzer, you can use a 12V relay to connect supply to the siren.) Once the operator has taken cognizance of the warning, he may turn off the buzzer using 'buzzer defeat' switch S6.

Manual start/stop operation. Pushbutton switches S4 and S5 in conjunction with relays RL2 (start control) and RL3 (stop control) are used to manually control the DG set when the mode switch in the ATS is kept in 'manual' mode. For starting the DG set, 'start' button is kept pressed and released as soon as the engine picks up speed.

Start-control relay energises via the de-energised contacts of stop-control relay RL3. Similarly, energisation of stop-control relay RL3 is possible via the de-energised contacts of relay RL2. This provides a safety against any erroneous pressing of a button while the automatic mode is in operation, and avoids simultaneous operation of 'start' and 'stop' solenoids.

The rest of 'start'/'stop' operation is similar to that of the automatic operation, with the exception of timer relay RL4, which is bypassed during the manual stop operation. ***(Caution:*** Don't release 'Stop' pushbutton until the engine comes to a dead stop. Else, the engine will tend to restart because of its flywheel inertia.)

'Reset start' tactile switch S1 has been provided for resetting the start operation prematurely during circuit testing. For detecting the manual-to-auto mode transition at the ATS, transition-detection mono IC13 has been

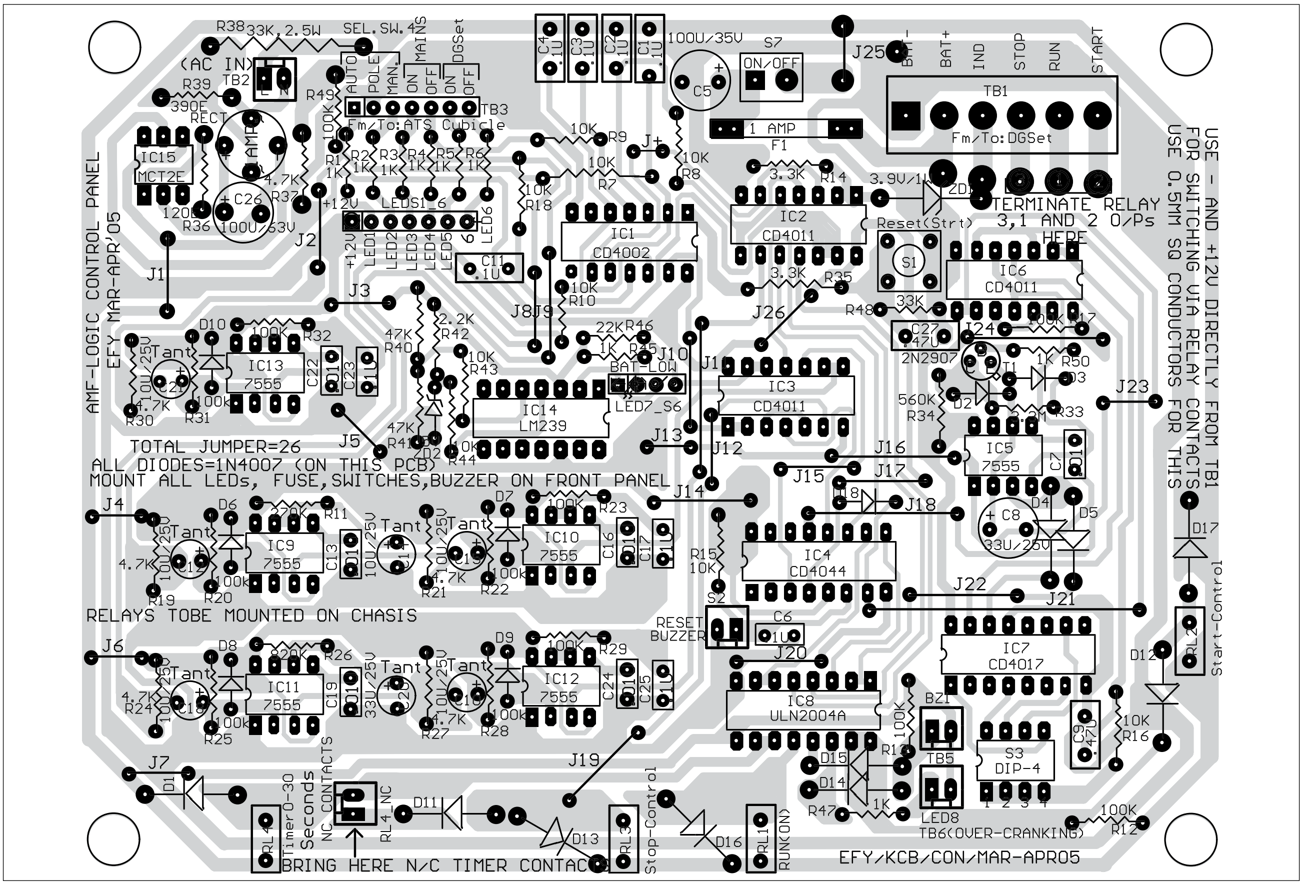


Fig. 15: Component layout for the PCB

used, which provides a reset pulse for start and stop latches of CD4044 (IC4).

PCB and assembly

A single-side, actual-size PCB for the logic circuit (Fig. 12) is shown in Fig. 14 and its component layout in Fig. 15. The front panel of the proposed enclosure for the logic control PCB including all the components (to be mounted externally on its chassis) is shown in Fig. 16.

All the status LEDs, buzzer and switches shown in Fig. 12 (except tactile switch S1) are mounted on the front panel. Suitable Bergstick connectors (male/females) should be used for extending the connections for the LEDs, switches and the buzzer. For the purpose, SIP connectors have been provided on the PCB.

All the cable entries to various TBs should be made from the rear. Use a 1-sq.mm flexible conductor wire for supplying the DC voltage from the DG set to the logic control panel. For the remaining external control signals, a 0.25-sq.mm flexible wiring will suffice. Cartridge fuse holder for fuse F1 and toggle switch S7 may also be mounted on the rear panel, close to TB1.

Mount all the relays (RL1 through RL4) horizontally on the chassis of the panel. DC supply (±12V) to the relay contacts is provided directly from TB-1 terminals using 0.5mm^2 flexible wires. Mark all the external wires using ferrules as shown in the interconnection diagram.

Testing

Test each part of the circuit elaborately by making use of the status-indication lamps and logic explained for various parts of the circuit without extending connections from TB-1 terminals 4, 5 and 6 to the DG set. Use 12V lamps (of 2 to 3 watts) or even LEDs connected to these terminals for testing the circuit operation before connecting them to the corresponding terminals of the DG set. As far as connections to the ATS via TB-2 are concerned, we are merely carrying negative DC supply via its pin 2 for return via other pins of TB-2. Hence there is no danger unless you mix up the wires with 415/230 AC voltages present in the ATS cubicle.

Things to remember

1. Many a times, the power supply (mains 3-phase) maintenance personnel inadvertently interchange the phases during reconnection after servicing. The resulting phase reversal can have very serious repercussions in organisations employing 3-phase motor operated machinery due to reverse rotation of the motors.

The Minilec phase-reversal prevention relay (VMR D2) installed in the ATS cubicle senses this reversal and trips to prevent the control voltage (red phase) from exercising automatic changeover control. Tripping is indicated by an LED on the VMR D2 relay.

Tripping can also be caused by single-phasing or under-/over-voltage of the 3-phase supply. Hence check that all the three phase voltages are within limits. Once you are satisfied that 3-phase voltages are alright, the most probable cause is loss of phase sequence. If you have a phase-sequence indication meter, you can verify the same.

To correct the phase sequence, first isolate mains and interchange any two of its phase wires going to the ATS—preferably, Y- and B-phase wires since the red-phase wire is used for control in the ATS. In case you are not using any phase-sensitive load, simply interchange the Y and B phase wires on the Minilec relay itself, ensuring (in both cases) that the trip LED goes off when all the three phases of the supply are available. This will enable automatic changeover when mains is available.

2. After any maintenance of the DG set, ensure that all the phase wires are connected correctly. Else, changeover to the DG set supply will not take place for the reasons explained above. Also make sure that the dynamo terminals are properly plugged and battery charging is being indicated by the ammeter on the DG set instrument panel when the engine is running and the keyswitch is in 'on' position. If the filament of the bulb in the charging path is open-circuited, then also the battery charging will not take place.

3. Use good-quality contactors, relays and timers from companies like L&T, BCH, Siemens, Minilec, Havell, English Electric, PLA, OEN or Omron.

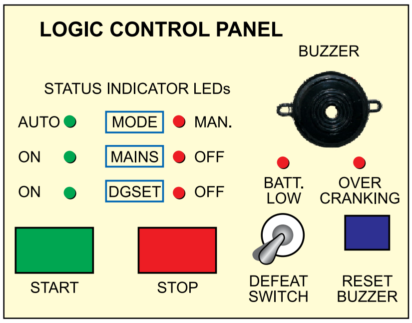


Fig. 16: Front panel of the proposed enclosure for assembling the logic control PCB

Conclusions

Users may modify the circuits appropriately for meeting the specific requirements of their standby supply sources. It is also possible to reduce the AMF control panel circuitry to just the use of peripheral components by employing a microcontroller to implement the basic logic. So good luck!