# R632
# SEQUENCE & PROTECTION (S&P) MODULE

## I. INTRODUCTION

The S & P Module must be used for any of the following options associated with the controlled rectifier.

1. External command control
2. External status information
3. Specific fault information
4. Fault recycling
5. Manual/Automatic operation
6. Load Sharing

External command control refers to external operator commands such as Start, Stop, GPS (Gate Pulse Suppression) Reset or Emergency Stop.

External status information refers to external ON, OFF, READY and FAULT lights and to an auxiliary set of relay contacts for external sequence interfacing if required.

Specific fault information refers to the positive identification of which fault has occurred. These faults are Undervoltage (UV), Instantaneous Overcurrent (OC), and Inverse Time Overload (ITOL) and are uniquely identified by LED's (light emitting diodes) on the S & P Module.

The undervoltage trip circuit is used to detect a reduction in main power. The trip point is adjustable with 1P on the S & P Module and should be set to detect a trip level at 80% of rated main power voltage. The adjustment on the trip level is required because the selection of descrete synchronizing transformer voltages operates the synchronizing transformer at or below rated voltage. The Instantaneous Overcurrent trip circuit is used to detect an instantaneous overcurrent condition. The detection circuit is on the Driver Module and an adjustment potentiometer (1P on the driver module) can be used to set the trip level between 125% and 225% of rated system current. The Inverse Time Overload circuit is an optional function which is mounted on the S & P module. The following curve defines the operation of the ITOL circuit. When the current feedback signal is from the Current Sensor S#1888A75G03 which provides amplification and isolation from the power circuit, the feedback signal is limited to 225% of rated current (5 x 2.25 = 11.25V).

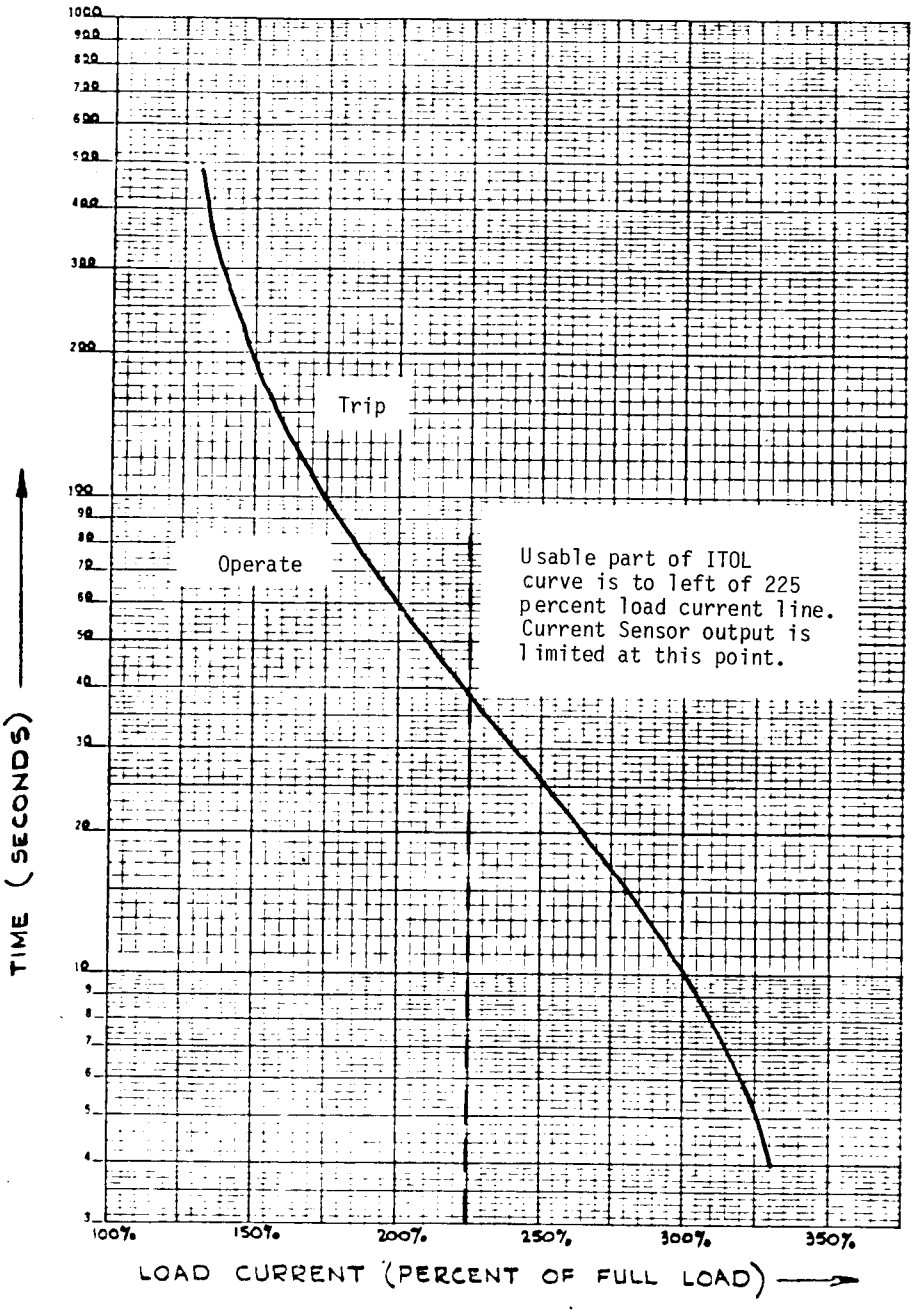
Fault recycling refers to an operating option in which the regulator resets itself when a fault occurs and automatically attempts to restart without any external commands. There are two operating modes of fault recycling. An OC (overcurrent) or UV (undervoltage) fault causes immediate gate pulse suppression and controller reset. Once this suppression/reset condition has been generated, the pulse stretcher on the Driver Module holds the system suppressed for 100ms. After this time period, the system is automatically restarted under ramp control. If an ITOL (Inverse Time Overload) fault is detected, the system stops by resetting of the RFG (ramp function generator) reference inputs. This reset exists for a period of 15 seconds following which the RFG input references are released and the system restarts under ramp control. After an ITOL fault, the external fault indication cannot be cleared until the 15 second time period has elapsed.

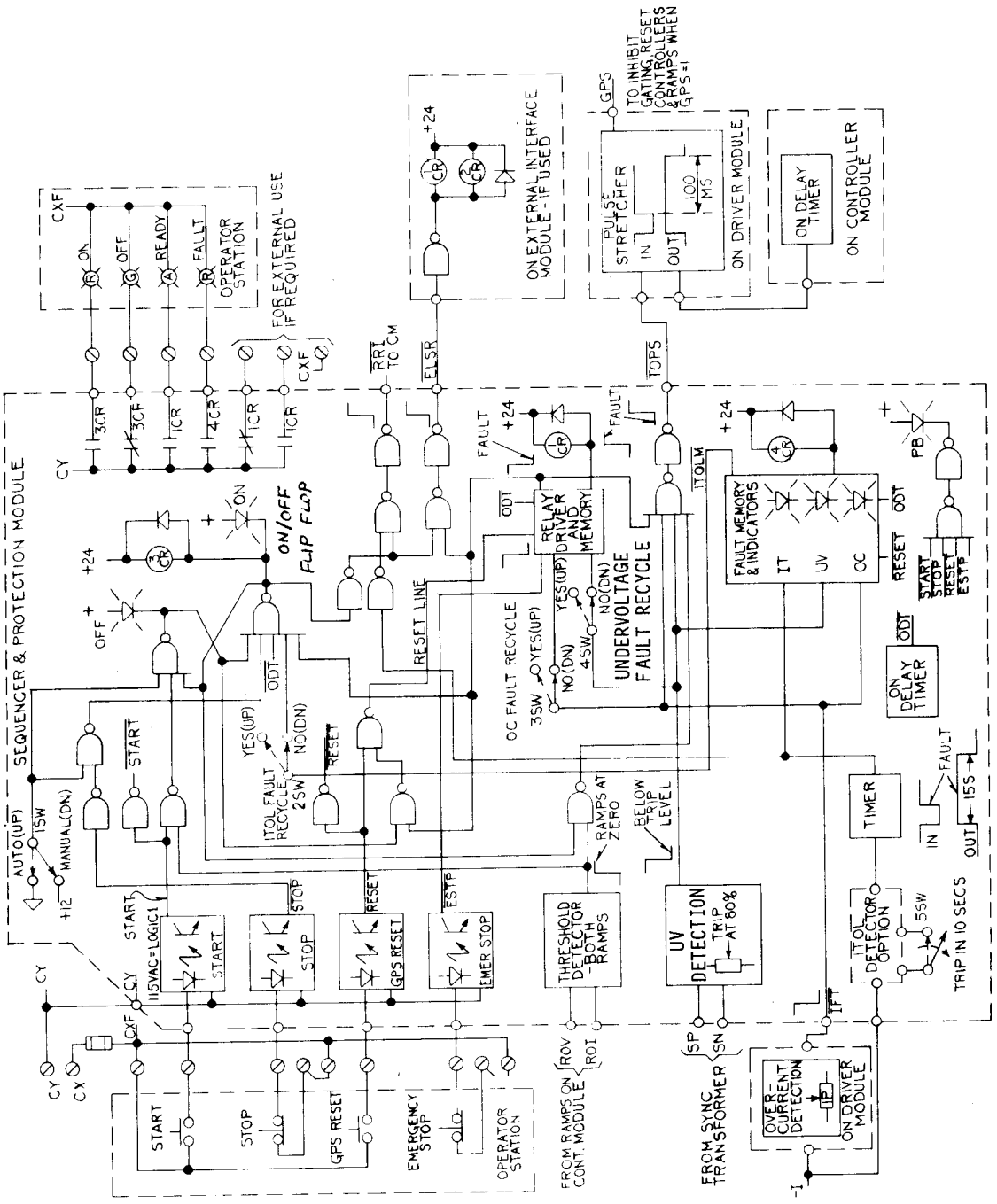
Manual/Automatic operation refers to operation of the system either with or without external Start/Stop command information.

When operating parallel rectifiers in a voltage regulating mode with droop, the S & P Module is required in order to provide a means of disconnecting a system from the load share scheme in the event its regulator goes off line.

This module provides electronic hardware to implement these options. If the operator station is to be used to sequence and monitor the regulator, this module provides isolated communication lines between 115V ac used externally and the logic levels used in the regulator. This module provides the circuitry for optional fault detection and indication. The logic required to control the regulator, either from commands from the operator station or from a detected fault condition, is contained on this card.

INVERSE TIME OVER LOAD CURVE






SIMPLIFIED SCHEMATIC OF S & P MODULE WITH SOME EXTERNAL CIRCUITS

FIGURE 1

A simplified schematic of the module is shown in Figure 1. Some of the schematic parts are external to the module but they are shown to aid in the discussion.

II. BASIC OPERATION (See Figure 1)

When the S & P Module option is used, input command signals from the operator station pushbuttons are optically coupled into the logic circuitry. Output signals for external communication, either operator station lights or external sequencing, are isolated by relay contacts. If contacts of 1CR are used for external sequencing, the interface relay must have a noise suppressor.

The Operator Station contains four pushbuttons: Start, Stop, GPS Reset and Emergency Stop and four lights ON, OFF, Ready and Fault. The Start and Stop pushbuttons cause the regulator to start and stop in a controlled fashion (soft start with a ramp function generator). The GPS Reset pushbutton resets the fault circuits on the S & P Module. The Emergency Stop pushbutton stops the regulator in an uncontrolled fashion: pulses are inhibited and all controllers are reset. The Start and Stop lights normally indicate that a Start or Stop command has been initiated. The Ready light indicates that all fault circuitry has been reset. The Fault light indicates that a fault has occurred.

In the following discussion, it is assumed that auxiliary power is applied to the regulator before main power is applied. When the regulator is operated with the S & P Module, the initial state of the regulator is the reset mode with all controllers reset and all gating inhibited. This initial condition is established by an on delay timer which cycles when auxiliary power is applied. When the timer times out, a fault will be generated by the UV Detector block which monitors main (synchronizing) power. It is assumed that the regulator is not in the fault recycle mode (to be discussed later) and this fault will permanently reset the regulator until the fault condition is cleared and the fault circuitry is reset. On the Operator Station, the OFF and FAULT lights will be on. When main power is applied, the GPS Reset pushbutton on the Operator Station can be used to reset the fault circuitry. When a reset is initiated, the Fault light on the Operator Station will extinguish and the Ready light will light.

On the S & P Module, the fault LED's (Light Emitting Diodes) as well as the ON LED will be out. The OFF LED will be on. These latter two LED's correspond to the ON/OFF lights on the operator panel. On the Operator Station, the OFF light will be lit and the ON light will be extinguished. With the Ready light on, the regulator can be started.

If auxiliary and main power are applied simultaneously, the regulator should be automatically reset into the Stop condition with all faults cleared. Operation can be initiated by a start command.

When a Start command is initiated, the signal is coupled into the regulator and the ON/OFF flip flop, comprised of cross coupled NAND gates, is set. The flip flop causes the OFF LED to go out and the ON LED to light. Also, relay 3CR energizes and the OFF/ON lights on the operator station change state: ON lit, OFF extinguished. A signal from the flip flop is applied to two NAND gates. One output ($\overline{RRI}$) is applied to the Controller Module and releases the input circuit to the ramp function generator (RFG). The RFG when operable causes the reference signal to be ramped up from 0 to its preset value, thus giving a "soft start". A second output ($\overline{TOPS}$) causes the Pulse Stretcher circuit to release; and after the 100ms timing period of this circuitry, gate pulses are allowed to be generated and the ramp function generators and controllers are released. The pulse stretcher is used to insure that once an input (which may be transient in nature) is received the timing sequence is completed before allowing any subsequent sequencing or operation.

At this point the regulator will regulate for the required parameters as determined by the input reference signals.

If a stop command is initiated, this signal is coupled into the regulator and the ON/OFF flip flop is reset. The OFF LED will light, the ON LED will extinguish and with 3CR de-energizing the ON/OFF lights on the operator station will change state. An output signal from the flip flop causes the signal $\overline{RRI}$ to go low, which in turn causes the reference inputs to the ramps to be reset. This will cause the references to ramp down from their set points. A threshold detector monitors the output of both ramps on the Controller Module. When both ramps are at within 100mV of zero the threshold detector generates an output signal which combines with a signal from the ON/OFF flip flop to create a low $\overline{TOPS}$ signal which triggers the pulse stretcher. The pulse stretcher output is used to inhibit all gating and to reset the controllers and ramps.

There are three fault detection blocks. Their functional operation will be discussed first. If the regulator is operational (having been started) and a fault occurs the following action will take place. This is valid for an undervoltage condition or an instantaneous overcurrent condition.

The output signals (logic 0's) from these fault blocks are applied to the Relay Driver and Memory, the Pulse Stretcher and the Fault Memory and Indicator blocks.

The Relay Driver and Memory block seals in when a fault is generated. Output signals from this block reset the ON/OFF flip flop and de-energize relay 1CR. Both the Ready light and the ON light on the operator station will be extinguished.

The fault output signals as well as a signal from the Relay Driver and Memory block are applied to the Pulse Stretcher which causes the system to be in the inhibit/reset mode.

The fault output signals are applied to the Fault Memory and Indicator block for fault diagnosis. Relay 4CR will be energized and the Fault light on the operator console will be lit.

The regulator will stay in the inhibit/reset mode until an external GPS Reset command is generated. This command is coupled into the regulator. The $\overline{\text{RESET}}$ signal resets the Fault Memory and Indicator block causing relay 4CR to de-energize extinguishing the Fault light on the operator console. When the system has faulted, the RESET signal resets the Relay Driver and Memory block and the Ready light on the operator console will relight. The regulator can now be restarted with a Start command. If the fault has not cleared, the fault indication will be re-established.

If an Inverse Time Overload (ITOL) fault is detected, the output from this block does the same thing as a Stop command and in addition causes the Fault Memory and Indicator block to indicate an ITOL fault. This will cause the OFF & FAULT lights on the operators console to be lit, but the READY light will still be on. While the system can be restarted with a Start command, the fault circuitry should be reset before this is done in order to clear the fault LED's and the fault light. After a 15 second delay, the external GPS Reset pushbutton can be used to clear the fault indication. The fault LED's indicate only the first fault received and subsequent fault information will be lost if the fault circuitry is not cleared.

The Fault Memory and Indicator block which identifies the occurrence of a fault - UV, OC and ITOL (if selected) operates on a first come first served basis. That is, only the first fault in a fault occurrence is detected. When a fault has occurred the LED's on the S & P Module should be checked to determine and log the type of fault. When faults are operated in the non-recycled mode it is necessary to activate the GPS Reset pushbutton to clear the fault circuitry before a restart can be initiated. However, if faults are operated in the recycled mode, operation with a fault indication is possible. If this fault information is not recorded and the fault circuitry subsequently reset, additional fault information will be lost due to the first come first served operation of this circuitry.

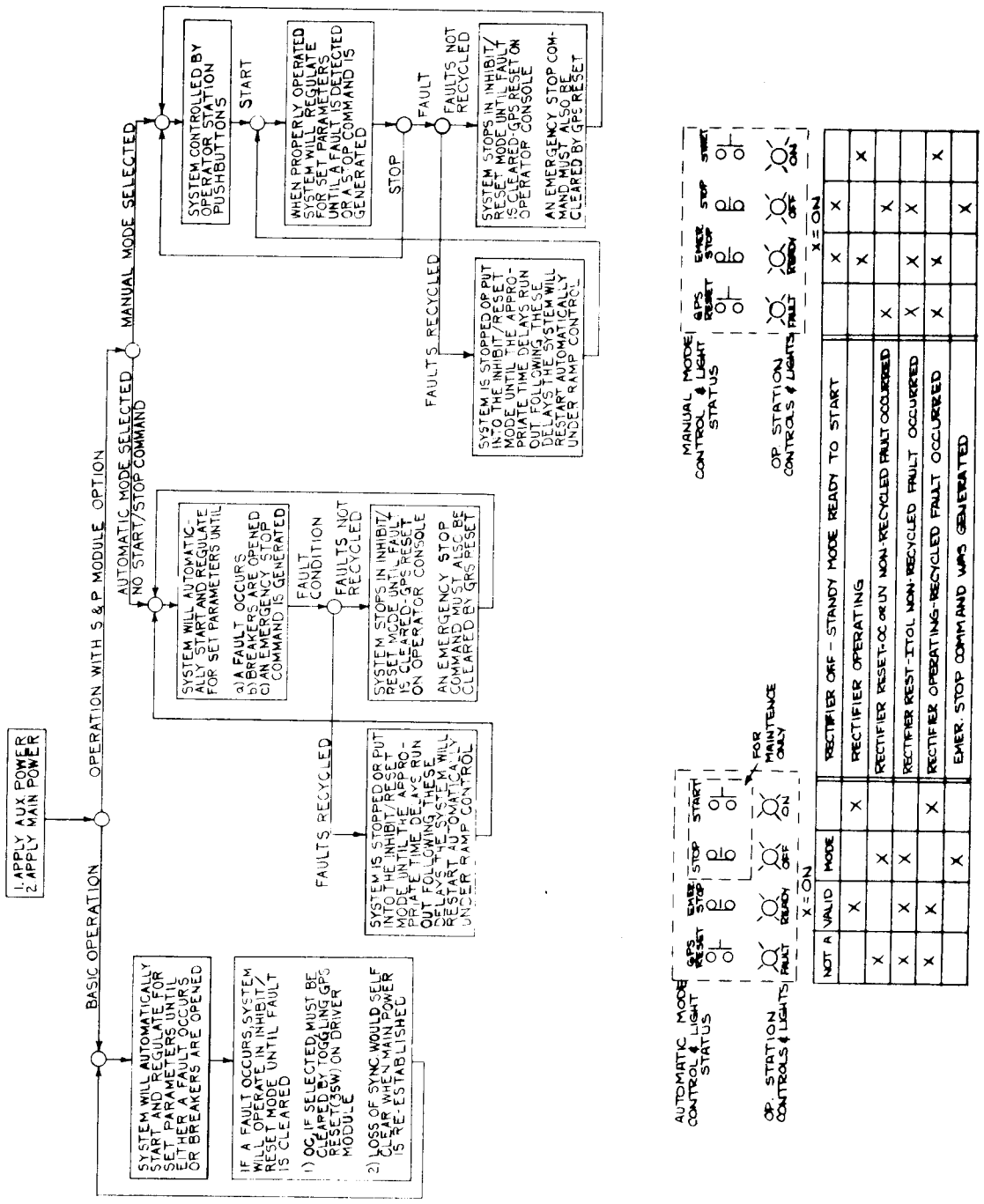
An Emergency Stop command is coupled into the regulator and triggers the Relay Driver and Memory circuit. This will cause the regulator to go into an instantaneous inhibit/reset mode. In this instance the Ready and ON lights will extinguish and the OFF light will come on. This is essentially the same condition generated by a fault except that no fault light is lit.

## III. OPERATOR STATION CONTROL & LIGHT INFORMATION

There are four lights on the Operator Station: Ready, On, Off and Fault. The Ready light must be on and generally the Fault light must be off in order to turn the regulator on. If either of these lights is in the incorrect state, the GPS Reset pushbutton must be depressed to properly establish the regulator status. Once this has been done, the ON pushbutton can be depressed to start the regulator. At this time the OFF light would extinguish and the ON light would come on.

From a running condition there are several things that can happen to change the regulator status and light indications. If the OFF pushbutton is depressed, the ON light will extinguish and the OFF light will light. The Ready light will still be on, and once the system has ramped down to zero the regulator can be restarted. If the Ready light goes out without a fault indication, this means that an Emergency Stop signal was generated. If the Fault light is on with the regulator still running, this means that a selected recycle fault occurred. The fault LED's should be checked and recorded in the station log and the GPS Reset should be depressed to clear the fault indication. If the Fault light is on with the regulator in the OFF mode and the Ready light still on, this means that an ITOL fault occurred. If the Fault light is on with regulator in the OFF mode and the Ready light is also off, this means that a non-recycled OC or UV fault signal occurred. Any time the Fault light is on or the Ready light is out, regulator status must be reset by depressing GPS Reset. Any time the Fault light is on, whether the regulator is operating or reset, the fault LED's on the S & P Module should be checked to determine which fault occurred; and the GPS Reset should be depressed to clear the fault circuitry.

See Figure 2 which summarizes the various light conditions.




| NOT A | VALID | MODE | | RECTIFIER OFF - STANDY MODE READY TO START | X | X | |
|---|---|---|---|---|---|---|---|
| | X | | X | RECTIFIER OPERATING | | X | X |
| X | | X | | RECTIFIER RESET-OC OR UV NON-RECYCLED FAULT OCCURRED | X | | X |
| X | X | X | | RECTIFIER REST-ITOL NON-RECYCLED FAULT OCCURRED | X | X | X |
| X | X | | X | RECTIFIER OPERATING-RECYCLED FAULT OCCURRED | X | X | |
| | | X | | EMER. STOP COMMAND WAS GENERATED | | | X |

SYSTEM OPERATION & OPERATOR LIGHT CONDITIONS

FIGURE 2

## IV. FAULT RECYCLING

The following discussion pertains to operation of the regulator in a fault recycle mode under the assumption that the regulator is already operating (having been started). Other options relative to sequence control when the fault recycle option is used will be discussed in a later section.

Fault Recycling in the regulator forces the regulator into either an inhibit/reset mode (pulsing inhibited and controllers and ramps reset) or a time delayed stop mode when a selected fault occurs. The inhibit/reset mode is used when either an OC or an UV fault, if selected for recycling, occurs. For these faults the regulator is held in this mode for the duration of the fault plus 100ms (time interval of the pulse stretcher) following which the regulator will automatically restart in a fashion similar to a normal start. If the ITOL fault is recycled then, when a fault indication is generated, the reference input to the ramp is reset for 15 seconds. This forces the system to ramp down to zero and to hold in this mode until the 15 second timer has elapsed following which the system will be allowed to ramp up to its required operating level.

The fault recycling of an ITOL fault is different from the fault recycling of the OC or UV faults. An ITOL fault is a thermal condition which requires a change in operation while the OC and UV fault conditions require immediate action.

The inhibit/reset fault recycle mode can be selected for either or both the OC or UV faults depending upon system requirements. If this mode is selected, the appropriate fault signal(s) is (are) prevented from being applied to the Relay Driver and Memory block. The fault signal is applied to the Pulse Stretcher block which Inhibits/Resets the regulator for the duration of the fault plus 100ms. The fault signal is applied to the Fault Memory and Indicators block to indicate that a fault occurred and which type of fault it was (appropriate LED).

When the ITOL fault is recycled, the timer output is applied to two places. One circuit forces the $\overline{RRI}$ signal to the low state. This signal resets the input reference to the ramps forcing the ramps to ramp down to zero and to hold there until the timer times out. The input to the Fault Memory and Indicators block causes a fault indication to be generated and turns on the appropriate LED. When this fault is recycled, the $\overline{ITOLM}$ signal is prevented from being applied to the ON/OFF flip flop which would normally force the regulator into a stop mode.

From an operator standpoint, the following information would be available. On the operator console the system would still appear to be on; ON light lit: READY light lit. However, the Fault light would also be lit. This would indicate that a recycled fault had occurred. If current and voltage metering were available, it would indicate that the fault had occurred in the past. If the current and voltage metering were at zero they would indicate that the fault still existed or that the appropriate timers had not yet timed out. Also the current and voltage meters could show a continuing recycle which could happen if the instantaneous overcurrent fault was selected for recycling and the regulator kept tripping out everytime the current increased to the trip level presumably because of a load problem. The LED's on the S & P module should be checked to identify the type of fault following which the fault circuitry should be reset (GPS Reset) to allow subsequent fault information to become available.

## V. REGULATOR CONTROL

As shown in Figure 1 there are four operator pushbuttons normally used to control the regulator.

| | |
|---|---|
| START | Starts the regulator if the FAULT light is out and the READY light is on. The regulator will ramp up to the reference point. |
| STOP | Stops the regulator. The regulator will ramp down to zero from its reference point following which it will go into an inhibit/reset mode. |
| GPS RESET | Resets the regulator if it has faulted. If the regulator has stopped because of a fault, this pushbutton must be activated to clear the regulator. If a fault is indicated while the regulator is still running as when fault recycling, this pushbutton clears only the fault memory and indicator block. |
| EMER. STOP | Causes an immediate inhibit/reset condition in the regulator. |

In normal operation, auxiliary power could be applied first. The regulator would indicate a fault due to the lack of synchronizing voltages. When main power is applied, the fault can be cleared and the regulator can be started.

Alternatively main power could be applied before, or at the same time as, auxiliary power in which case a fault would not be generated. The regulator can then be started.

In applications where the customer does not want start/stop control, switch 1SW on the S & P module should be transferred from the Manual position (DN) to the Auto position (UP). In this mode the Start/Stop pushbuttons are inoperative and they could either be left off the operator panel or they could be left on and used for a maintenance function when in the manual mode of operation.

In the Automatic Mode, if main power is applied before or at the same time as auxiliary power, the regulator will automatically start when the On Delay Timer on the Driver Module times out. If a fault occurs, the regulator will shutdown and when the GPS Reset is activated to clear the fault the regulator will automatically restart if the fault clears. In this mode the Emergency Stop pushbutton could be used as a stop command except that the regulator would immediately go into an inhibit/reset mode as opposed to a normal ramped stop.

When the Automatic Mode is selected, all light indicators are the same except for the ON, OFF LED's on the S & P modules. In this mode the OFF LED will always be off. The ON LED will normally be ON and will extinguish only whan a non-recycled fault or an emergency stop signal is generated.

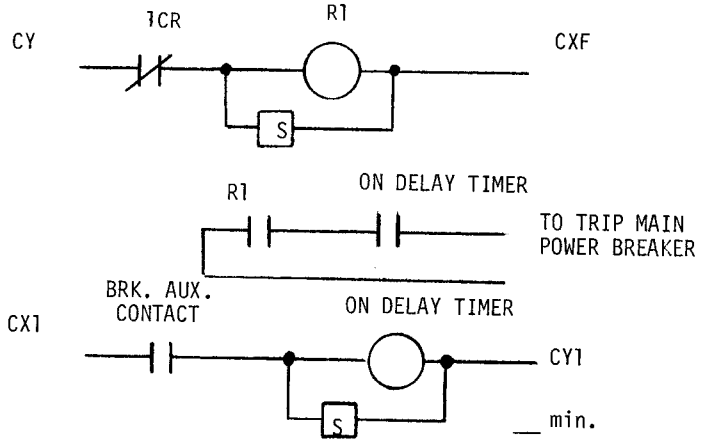
The Automatic Mode can also be used with the Fault Recycle mode. For example, if the UV fault circuitry is operated in the recycle mode, the Regulator will operate similar to a controlled rectifier with separate auxiliary power. Auxiliary power can be applied and the regulator will hold in the inhibit/reset mode until main power is applied. When main power is applied, the Pulse Stretcher will time out and the regulator will regulate as required. In this case a fault light would be lit on the operator console. This light can be cleared with the GPS Reset push-button without changing the regulator operating condition.

In the Automatic mode, a non-recycled OC or UV fault or a non-recycled Inverse Time Overload (if used) fault will shut down the regulator. An ITOL condition will cause the regulator to ramp down to zero before going into an inhibit/reset mode. An OC or UV fault will cause an immediate inhibit/reset condition. From an operator standpoint, the Fault light on while still operating indicates that a recycled fault has occurrred. The Fault light on with the Ready light out indicates either an OC or an UV non-recycled fault occurred. The Fault light on with the Ready light on, the On light off and the Off light on indicates that a non-recycled ITOL fault occurred. The LED's on the S & P module should be checked to determine which condition turned off the regulator.

## VI. OUTPUT RELAY CONTACTS

Output relay contacts are used to isolate the regulator from 115V ac used on the operator station. Output relay contacts are used to properly sequence the lights on the operator station. Contacts of 1CR (the Ready function) are supplied for possible external communication if required. Any relay connected to these contacts must be suppressed.

If contacts of relay 1CR are required to trip the main ac power breaker, there is a sequencing problem which might have to be handled in the following fashion.




The ON DELAY TIMER is required so that once the breaker is reclosed, some time is provided to allow clearing of the fault indication in the regulator which normally causes the breaker to trip.

Normally open contacts of relays 1CR and 2CR mounted on the External Interface Module are used to provide a disconnect for the average current signal when parallel regulators are operated in the voltage regulating mode with load balancing. These contacts will disconnect the average current signal from the load balance scheme if the regulator goes off line for some reason. If a regulator is operated with load balance, fault recycling should not be used.

## VII. SEQUENCE FLOW DIAGRAM

Figure 2 indicates the basic modes of operation of the system. In addition, tables are provided to identify the operating or fault condition of the system as indicated by the operator station lights.

## VIII. SWITCH SELECTION

The following switches on the S & P Module are used to establish the operating mode.

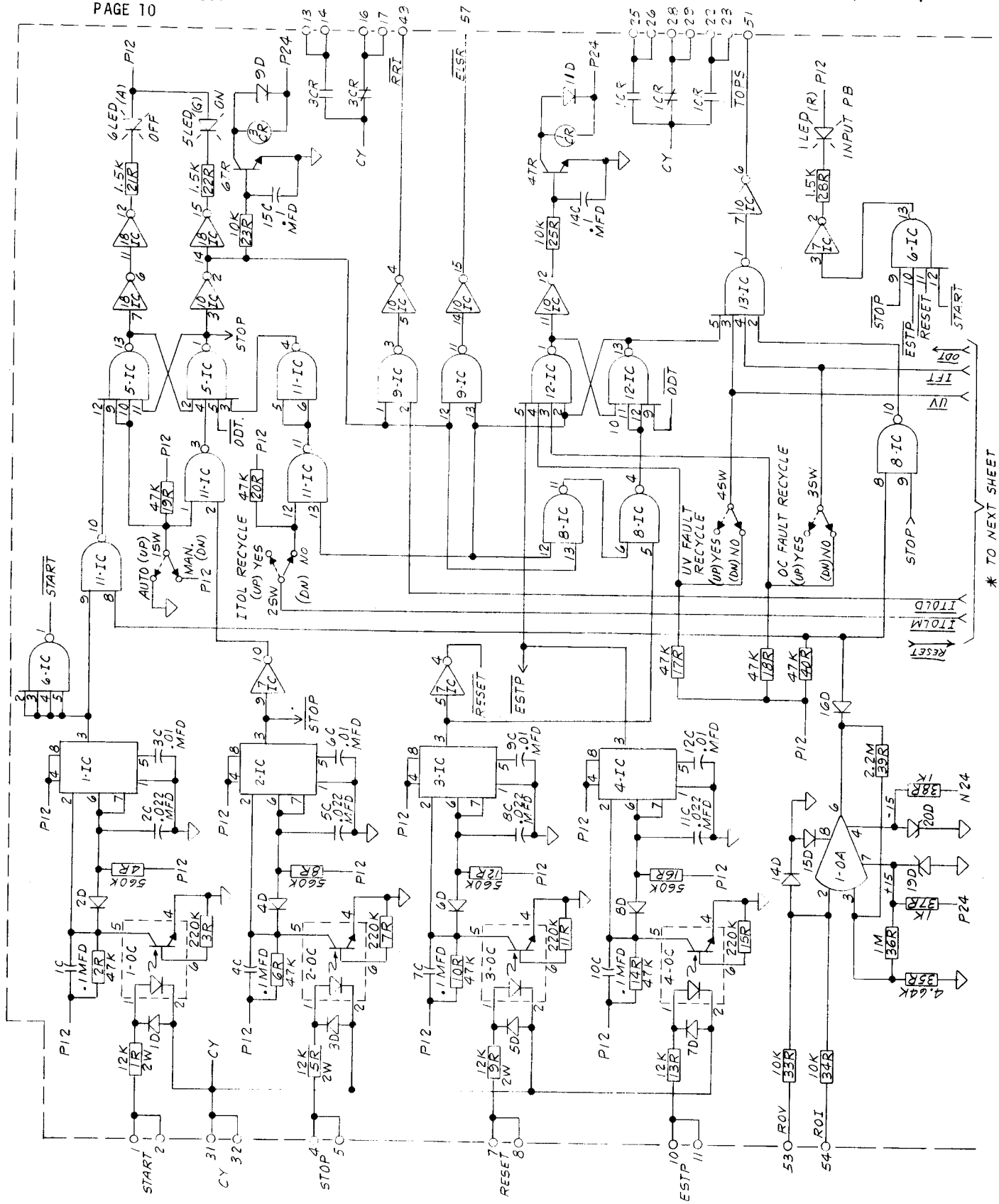
| | | |
|---|---|---|
| 1SW | (UP) | Automatic mode of operation |
| | (DN) | Manual mode of operation |
| 2SW | (UP) | Recycle on ITOL fault |
| | (DN) | Do not recycle on ITOL fault |
| 3SW | (UP) | Recycle on OC fault |
| | (DN) | Do not recycle on OC fault |
| 4SW | (UP) | Recycle on UV fault |
| | (DN) | Do not recycle on UN fault |
| 5SW | | When the ITOL option is selected, this toggle switch when raised causes an ITOL fault in 10 seconds. (Spring Return Switch). |

## IX. ITOL OPTION

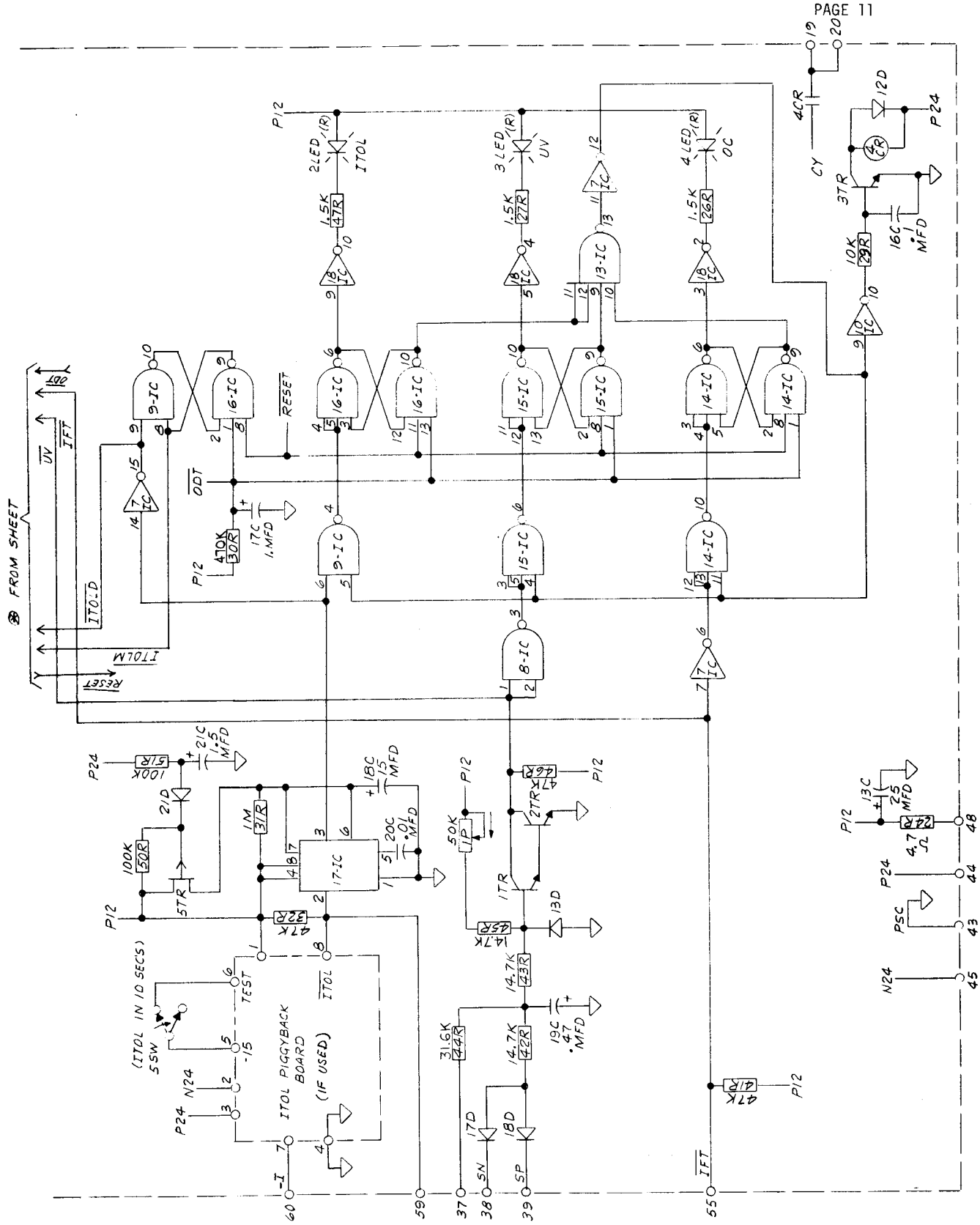
The ITOL option must be selected when the regulator panel for the rectifier is specified.

## X. PUSHBUTTON CHECK

Indicating LED PB provides a check on the external pushbuttons and wiring and the input optical couplers. This LED will normally be extinguished and should light when any of the external pushbuttons are depressed. If this LED is lit at any other time, something is wrong either externally or internally.




R632 SEQUENCE & PROTECTION MODULE PART A




R632 SEQUENCE & PROTECTION MODUEL PART B

ITOL OPTION FOR
R632 SEQUENCE & PROTECTION MODULE