WRITE-UP

ON

AUTOMATIC TURBINE RUNUP SYSTEM

(MAX- DNA BASED)

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Rev	**Date**	**Remark**	**Prepared.**	**Checked**	**Approved**

1.0 INTRODUCTION :

A successful start-up of the turbine normally requires acquisition, analysis and collation of a wide variety of information pertaining to various parameters like oil pressure, vacuum, temperature, speed etc. Apart from this it is important to know the status of the auxiliary equipment. It is an arduous task for the operator to handle and collate so many bits of information, swiftly and correctly. A microprocessor based automatic run-up system performs this task swiftly, accurately and at an appropriate time. The chances of mal-operation due to human error in judgement of the situations, get practically eliminated.

2.0 CONCEPT :

The Programmable Automatic Turbine Run-up System (ATRS) is based on the 'Functional Group Control' philosophy. The control area is divided into clearly defined functional areas called 'Functional Groups'. Each functional group is organised and hierarchically arranged in Sub-Group Control (SGC), Sub-Loop Control (SLC) and Drive Interface Function .

Each functional group is realised in a Remote Processing Unit (RPU) which houses the Distributed Processing Unit (DPU), Input/output modules and the Communication Network. DPU is the process controller which executes control algorithms, sequence logic and data acquisition functions. Remote Processing Units (RPU) are connected to each other and operator workstations (OWS) through maxNET an ethernet communication network. The modules in a RPU communicate with each other through a I/O bus.

2.1 SUB-GROUP CONTROL :

SGC executes commands to bring the equipment upto a particular defined status. The commands are executed in a predefined sequence in the form of steps. Desired number of criteria act as preconditions before the SGC can take off or execute its defined sequence. The functional group continues to function automatically all the time demanding enabling criteria based on the process requirements and from other FGs, if required. In case the desired criteria is not available, the system would automatically act in such a manner as to ensure the safety of the main equipment.

The sequence is programmed in the processor. The process signals are acquired through the input modules and are available on the bus.

For each step there is a waiting time and a monitoring time which are defined below:

Waiting Time : It implies that the subsequent step will not be executed unless the specified time elapses. If no waiting time is specified, the next step gets executed as soon as the enabling criteria are fulfilled.

Monitoring Time : It is the time required for executing the command of any step as well as the time required for appearance of criteria for the next step. Under healthy conditions it should happen within the specified time, otherwise an alarm is initiated. Whenever there is uncertainty regarding the time required for completing a particular task, such as warming-up, pulling vacuum etc., the monitoring time is blocked.

ATRS can be switched on at any stage after completing certain tasks manually, if so desired. In such cases, the SGC program quickly scans through the steps and starts executing from the stage upto which the tasks have been completed manually. This is achieved by incorporating suitable overflow /bypass conditions in the logic.

SGC issues commands either to the SLC or directly to the drive through I/O modules.

ATRS is organised in the following five Sub-Groups :

- Oil supply
- Evacuation
- Turbine
- Control Fluid
- HPSU LP Bypass

Each of these SGCs has its subordinate SLCs and drive interface function These SGCs in conjunction with the turbine governing system , Turbine Stress Evaluator and the auto-synchroniser accomplish the function of start-up of the TG set.

2.1.1 Controls & Displays Available To Operator In A SGC :

Each subgroup control can be switched on and off from the operator workstation (OWS) . The 'Startup' and 'Shutdown' program can also be started manually from there.

The control display as shown in Fig-1 with standardised functions is provided on the operator workstation (OWS) for manual operations and indications of the sub-group control.

In case of auto-mode, control button 2 needs to be clicked upon for starting the program in 'operation' i.e. 'Startup' direction while click button 1 needs to be clicked upon for initiating the shutdown program. Steady light would appear in indication button 4 & 5 when the desired and defined status of mechanical equipment is achieved.

Indication Button 4 or 5 rapidly flashing, indicates that the program is running towards the desired status and there is no fault.

Indication Button 4 or 5 slowly flashing, indicates that the program is in the desired mode but a fault has appeared somewhere.

Steady indication in any of the indication buttons of step display indicates the step number in which the program exists in any given moment. Steady indication in step indication buttons and slow flashing indication in indication button 4 or 5 indicates that the program is stuck and there would also be steady indication in criterion indication buttons indicating which criterion has not been fulfilled.

2.1.2 **Method Of Representation & Other Features:**

a. In the logic diagram, the group control multifunction of subgroup control (SGC) is schematically represented as shown in Fig-2.1.

b. A typical step of subgroup control is represented as shown in Fig-2.2.

c. The steps for 'Startup' program are enumerated from 1 to 50 while the steps for 'Shutdown' program are enumerated from 51 to 99.

d. The signals hooked with protection channel 'P' have the highest priority and execute the logic even without seeking the availability of 'Release Criteria'.

2.2 **SUB-LOOP CONTROL (SLC) :**

A SLC, when switched on, actuates the equipment and brings it to the desired status as demanded by the process and there is no sequence logic involved in it. In other words, SLC is like a watch-dog performing an assigned duty. All mechanical equipment which need to be switched on/off based on process consideration are hooked-up in various SLCs. Standby equipment is also interlocked in SLCs.

SLC can be switched on either manually or through SGC and issues commands to the drive through I/O modules.

SLC logic is also realised in the DPU .

2.2.1 **Controls & Displays Available To Operator In A SLC:**

The control display with standardised functions is provided in the operator workstation (OWS) for manual operation and indication of the subloop control. Fig-3 indicates the control display for SLC.

2.3 DRIVE INTERFACE :

Each remote controlled drive has a drive interface software block which acts as a standard interface between the command transmitters and receivers in the plant and undertakes all necessary signal processing and monitoring.

The drive interface block receives manual commands from the OWS through Input modules active protection signals and enabling signals from the protective logic, as well as automatic control commands from the SGC/SLC. It interlocks the input commands according to their priority and validity and then passes actuation signals to drive through the output modules. The status checkbacks received from the switchgear or actuators are acquired through input modules, processed and transmitted to OWS, the protective logic and the SGC.The interposing relays for interfacing with switchgear are also housed in the control panels.

2.3.1 Control displays with standardised functions are provided on the OWS for manual control and checkback of the drives. A typical control display is indicated in Fig-4.1.

2.3.2 In the logic diagram, the control interface module is represented as shown in Fig 4.2.

2.3.3 For certain critical drives hardwired back up control tiles are provided on the control desk for operator interface.

3.0 MAXNET (Ethernet network) :

The MAXNET is the redundant ethernet network used for communication between the various RPUs as the part of the Turbine control system and the operator workstations allowing global access to all plant data. The maxNET Network consists of two completely independent ethernet networks to ensure maximum availability and fault tolerance.The network provides redundant communication networks with no single point of failure which can affect more than one station. The TCP/IP protocol is used for network communication .Switched hubs used in the maxNET network provide 100Mbps full duplex communication between switches, while network speed from switched hub to RPU and maxSTATION is 10Mbps.Switched hub enhance network performance and improve the network security.

4.0 MAX STATION SYSTEM:

The maxSTATION is the Man Machine Interface system for the MAX 1000+PLUS , Distributed Control System.It is a computer-based system with configurator, graphic displays data management software and associated hardware. It consists of operator's workstation and Engineer's workstation.

The operators workstation provides interface to the process with standard and custom displays. The control commands are issued by the operator to the drive interface through video Display Unit (VDU) and Keyboard (KBD) which are part of maxSTATION. An operator workstation is provided with the following type of displays

- Graphic displays
- Alarm displays
- Trend displays

Process alarms and events which originate at DPU are placed for use in the system and also on to the maxHistory Server for storage and analysis. Other alarms and events originating within maxSTATION are provided to the system by local status server of maxSTATION for reporting and archiving. For diagnostic purpose following types of alarms are provided

- Station Alarms
  - maxSTATION
  - Remote Processing Units, DPU, I/O
- Network Alarms
  - maxNET Alarms (e.g. Ethernet card failures, cable breaks or failed target station)

Engineer's workstation is used for creating and maintaining configuration and process control documentation using the maxTOOLS4E configurator software and for creating and maintaining custom graphic displays. maxTOOLS4E configurator performs the following functions:

- Identify and assign Distributed Processing Units , I/O modules ,and I/O signals in the Remote Processing Unit(RPU)
- Identify cabinet layout and placement of the above RPU components as well as power supplies , and other customer hardware
- Configure and assign Hierarchical Groups
- Configure Points
- Create configuration reports

5.0 **OPERATING MODES :**

In addition to the normal automatic mode of operation of the sub-group, the following two modes are also available :

Step-by-step-mode: In this mode, all the criteria for a particular step are simulated manually through the OWS and the command is issued automatically. This is helpful in case a criteria is actually fulfilled but the signal is not available to the sub-group because of a faulty transmitter.

Operator guide mode : In this mode, the sub-group only receives data from the plant and the control stations, but the output commands are blocked. The commands have to be issued manually from OWS. This mode is useful during commissioning and for operator training.

These modes can be selected from OWS, whenever desired.

6.0 ATRS STRUCTURE & DESCRIPTION OF SYSTEM:

ATRS is organised in three subgroup controls. These groups, in conjunction with the turbine governing system, Turbine Stress Evaluator/Controller (TSE/TSC) accomplish the various functions. The tasks assigned to each subgroup control are described below for a typical project. Actual logics may however vary from project to project.

6.1 Subgroup Control (SGC) Turbine :

SGC Turbine acts directly on the following systems :

1. Subloop Control (SLC) Drains.
2. Warm up Controller.
3. Starting Device of turbine governing system.
4. Speed & Load Setpoint devices of turbine governing system.
5. Auto-synchroniser.

SGC Turbine executes the following tasks, when switched ON. The operator manually switches on the SGC program at an appropriate time for running the turbine. The program takes off only after all the 'Release Criteria' are fulfilled.

6.1.1 Steam & metal Temperature matching:

The matching of steam & metal temperatures is an extremely important task before admitting the steam into the turbine for the purpose of warming up the various elements, speeding and subsequent loading. The ATRS accomplishes these tasks effectively and efficiently. Function generators are used to determine the desired level of temperature based on the actual metal temperature of the critical component (X- curves).

6.1.2 Warming-up:

ATRS acts on the warmup controller to ensure a safe rate warmup of the ESV & CV of HP turbine as permitted by the TSE. In the warmup stage, the operation of the turbine drains is equally important and all the drains are hooked up in a sub-loop control (SLC). Depending on the relative importance and significance of various drain valves, the criterion for opening/closing of each individual drain valve is defined and suitable logic built in to ensure safe operation. After the warming up of ESV & CV of the HP turbine, the ATRS admits steam into the turbine for rolling the turbine.

6.1.3 After ensuring adequate level of warming up and availability of all important criterion, the ATRS takes the turbine from the barring speed to the first hold speed which is approx. 20% of the rated speed. During the process of raising the speed, the acceleration is controlled by the TSE so that the components do not get overstressed. The ATRS ensure a definite hold for soaking of turbine internal at this speed for a specified period if the HP metal temperature is less than 250

°C, otherwise the hold period is determined by the time it takes for temperature margins of the TSE to be within permissible limits.

6.1.4 After proper and adequate thermal soaking of the components, the ATRS raises the speed of the TG set to rated speed. For this period also, the acceleration is controlled by TSE except for the region where rotors cross the critical speed zone. ATRS again ensures soaking as per process requirement and availability of margins.

6.1.5 After attaining a speed above 2950 rpm and when sufficient temperature are available, the auto-synchroniser takes over and matches the turbine speed to a value matching with the grid frequency. It simultaneously acts on the Automatic Voltage Regulator (AVR) for matching the grid and generator voltages. Auto-synchroniser synchronises the set at the right moment depending on the frequency and phase angle. EHG immediately enables the set to take 10% load.

6.1.6 ATRS switches on the tracking device, which tracks the hydraulic controller to the output of the electro-hydraulic controller with a set margin.

6.1.7 It facilitates the shutdown of the set in a proper sequence and switches on the SLC drains according to the process requirement.

6.2 **Sub-Group Control (SGC) - Oil Supply:**

SGC oil supply directly acts on the following system :

1. Subloop control (SLC) turning gear.
2. SLC auxiliary oil pump 1.
3. SLC auxiliary oil pump 2.
4. SLC emergency oil pump.
5. SLC jacking oil pump 1&2.

SGC oil supply performs the tasks as described in the subsequent paragraphs and simultaneously prepares the oil system to meet the situational demands of the main set by employing the technique of recycling.

6.2.1 Auxiliary oil pump no. 1 is switched on as first step to provide the lubricating and control fluid at the required ends.

6.2.2 The program switches on the oil temperature controller. The oil temperature controller provides an analog control to maintain the oil temperature in the header supplying oil to the bearings. The controller actuates a three-way valve thereby controlling the quantity of oil being cooled in the oil cooler and the quantity of oil being taken directly from the tank to the header.

The program only switches on the temperature controller and does not check back the actual oil temperature for the reason that all operations on the lub. oil system can be performed even if the oil temperature is not at the desired level. However, the availability of oil at the desired level of temperature is important for the actual rolling and therefore the oil temperature is checked as the "Enabling Criteria" in the program before turbine is rolled.

6.2.3 SGC lub. oil supply system ensures the supply of motive oil to the hydraulic turbine of turning gear as the SLC turning gear is switched "ON" by the SGC supply. The SLC logic is such that it opens the gate valve supplying oil to the turning gear whenever the turbine speed is less than 200 rpm. Therefore while starting the turbine from the standstill condition or during coasting down, the oil supply to the turning gear is ensured. The oil supply to the turning gear is switched 'Off' when turbine speed exceeds 250 rpm or SLC turning gear is switched "Off". Since the requirements for the turning of the turbine can arise at any point of time during operation, the operation of the turning gear valve is hooked up in SLC mode.

6.2.4 The jacking oil pumps are also hooked up in SLC mode and SGC oil supply system switches on this SLC for jacking oil pump.

In case the turbine speed is below 510 rpm or falls below this value while coasting down, the JOP 1 gets switched "On". In case JOP 1 does not develop the desired amount of pressure, the command for starting JOP 2 is issued with a time lag of 5 secs. As soon as the turbine crosses 540 rpm, the JOP 1 gets switched off as per the logic of the SLC. However, JOP 2, if in service, will not get switched off as per SLC logic and operator would have to switch off the JOP 2.

6.2.5 SGC lub. oil supply also switches on the SLCs for auxiliary oil pumps 1 & 2, emergency oil pump (DC) so as to keep all the vital pumps ready for action, should an emergency arise or develop at any stage of the process.

6.2.6 If the turbine trips after attaining a speed of more than 540 rpm, the program is designed in such a manner so as to perform the tasks stated in para 6.2.3, 6.2.4 & 6.2.5. Similarly, if the turbine trips after the turbine attains 3000 rpm, the whole program of oil supply is recycled to ensure the turning of the turbine.

6.2.7 Shut down program of oil supply can only be started if HP casing temperature, both top and bottom is below 100 °C, as otherwise an inadvertent switching off could lead to the situation of no turning operation even when the turbine is hot.

All the vital pumps are switched off after the turbine comes to standstill position.

6.3 <u>Sub-Group Control (SGC) - Condensate & Evacuation :</u>

SGC condensate & evacuation acts directly on the following systems:

1. Sub-loop Control (SLC) condensate extraction pumps.
2. Starting ejector, if provided.
3. Main ejectors / vacuum pumps (as applicable).
4. Vacuum breaker.

The condensate pumps are hooked up in a SLC and the SGC switches on this SLC in step 01. The preselected pump is switched on by the SLC. If the pump which is running is not giving the required pressure, the other pump is switched on. Also, if "Main Steam Flow > 60%", both condensate pumps are switched "On".

Although 'SLC Drains' is primarily hooked up with 'SGC - Turbine', 'SGC - Condensate & Evacuation' also switches it on.

6.3.3 Before starting the evacuation process, the vacuum breaker valve is first closed and the seal steam supply valve is also closed. Gland Steam Controller is put on manual so that it is not able to open the seal steam supply valve.

6.3.4 If provided, the starting ejector is put into operation by opening the air isolating valves.

6.3.5 After checking that the starting ejector valves are open, the main ejectors are also put into operation by opening the isolating valves. However, if vacuum pumps are provided, both the pumps are switched on.

6.3.6 The gland steam controller is put on 'auto' after checking that the turbine is on barring and the condenser pressure is less than a preset value. The gland steam controller brings the pressure in the gland steam header to normal, while evacuation is in progress.

6.3.7 After the condenser pressure falls below 260 mbar, the starting ejector, if provided, is put out of operation as it is not effective after that.

6.3.8 The main ejectors/ vacuum pumps continue the task of pulling the vacuum until absolute pressure in condenser has reduced below 120 mbar and generator load is >5%. After these criteria are achieved, the preselected main ejector / vacuum pump continues running while the other one is stopped and acts as a standby.

6.3.9 In case condenser pressure again rises above 120 mbar, the standby vacuum pump/ejector is again put into operation.

6.3.10 The shutdown program can be initiated by the operator if the release conditions are present. Initially, all the ejectors / vacuum pumps are put out of operation. Then the vacuum breaker valve is opened to break the vacuum. Finally the SLC condensate pumps and the CEPs are switched off.

6.4 **<u>Sub-Group Control (SGC) – Control Fluid :</u>**

SGC Control fluid acts on the following system:

1. Sub loop Control Fluid pumps
2. Sub loop control Fluid heating
3. Control Fluid pumps
4. Control Fluid re-circulation pumps
5. Control Fluid temperature control valve

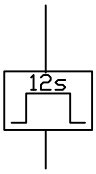
6.4.1 Both the CF pumps get switched ON through the SLC. In case the running pump does not develop the required pressure , the standby pump gets switched ON.

6.4.2 After getting the required CF pressure , SLC heating is put ON and CF circulation pump which feeds the regeneration circuit is also put ON. Temperature control valve is put in Auto mode to regulate the temperature.

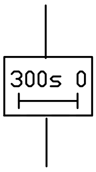
6.4.3 CF temperature in the tank is maintained between 55 to 57° C by switching ON/OFF the CF heater through the SLC. Additional safeguard is provided to switch OFF the heater in case the CF temperature in the heater exceeds 65° C.

6.4.4 In the shutdown program, all the oil pumps are switched OFF and an SLC CF pump is also put OFF. SLC heating is kept on to maintain the temperature required for the next start-up and can be manually switched off, if required.

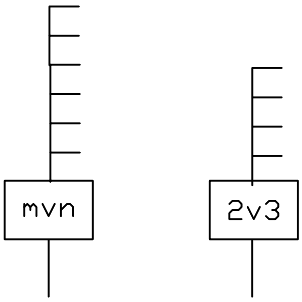
GRAPHIC SYMBOLS



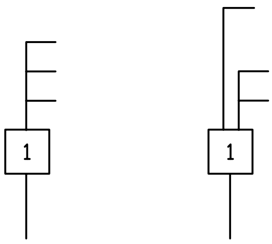
Signal Limitation (e.g. : 12 sec)
A continuous signal at the input appears at the output for 12 sec only.



On delay (e.g. : 300 sec)
The signal at the input appears with a delay of 300 sec at the output and remains until the input signal disappears.

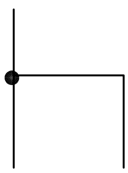


Voting Logic
There is a "1" signal at the output if at least m out of n input signals are "1" signals .(e.g. 2 out of 3)

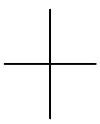


OR-condition

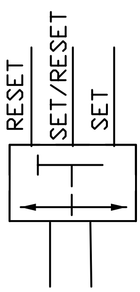
The mark "1" in the symbol may be replaced by the mark " 1" if ambiguities arise otherwise



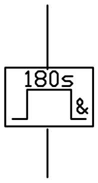
Signal branching



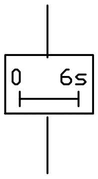
Signal crossing



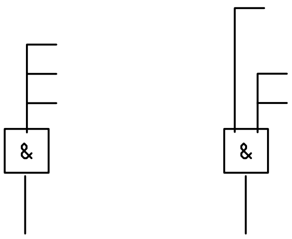
Signal memory with retaining function, without preferential position and with dynamic input :
Signal change from "0" to "1"



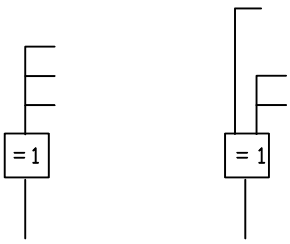
Signal lengthening
(and signal limitation with feedback)
e.g. : 180s
A pulse-type signal or a continuous signal at the input appears at the output for 180 sec



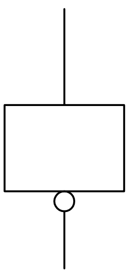
Drop off delay (e.g. : 6 sec)
When the signal at the input changes from "1" to "0", the output signal remains unchanged for the indicated time.



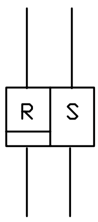
AND - condition



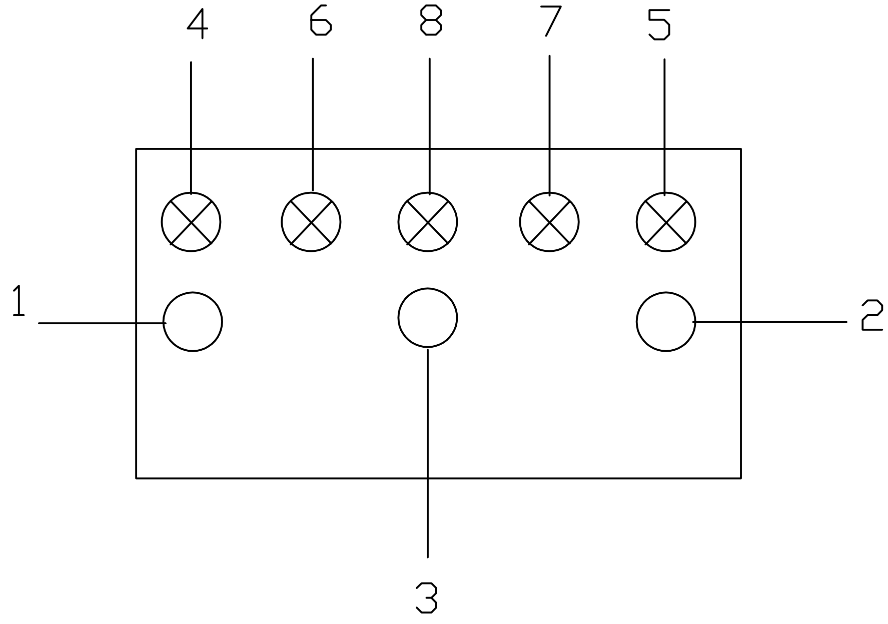
Exclusive OR



Signal Inversion (NOT)



Signal memory with preferential position on reset side



1. CONTROL BUTTON "SHUTDOWN"
2. CONTROL BUTTON "STARTUP" OR "OPERATION"
3. CONTROL BUTTON "AUTOMATIC ON/OFF"
4. INDICATION BUTTON "SHUTDOWN PROGRAM"
5. INDICATION BUTTON "STARTUP PROGRAM" OR "OPERATION PROGRAM"
6. INDICATION BUTTON "AUTOMATIC OFF"
7. INDICATION BUTTON "AUTOMATIC ON"
8. INDICATION BUTTON "FAULT"

FIG. 1 SGC DISPLAY

P	R	M	A	C	T	OFF	ON OFF	ON	S	C	A	M	R	P
SHUT DOWN										OPERATION				
GROUP CONTROL MULTIFUNCTION														

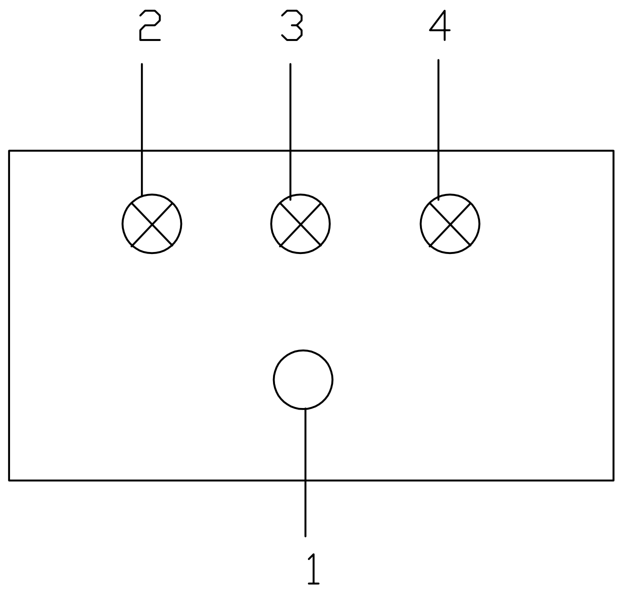
FIG. 2.1

FOR GRAPHICAL REPRESENTATION THE VARIOUS SIGNALS ARE HOOKED UP TO THE RESPECTIVE BOXES AS DESCRIBED.

P = PROTECTION COMMANDS
R = RELEASE SIGNAL
M = MANUAL COMMAND
A = AUTOMATIC COMMAND
} OFF/ON OR CLOSE/OPEN
C = SYSTEM CHECKBACK SIGNAL
T = OPERATOR GUIDE MODE WITHOUT COMMAND OUTPUT
OFF = AUTOMATIC COMMAND, SUBGROUP CONTROL OFF
ON/OFF = MANUAL COMMAND, SUBGROUP CONTROL ON/OFF
ON = AUTOMATIC COMMAND, SUBGROUP CONTROL ON
S = STEP MODE WITHOUT PROCESS CRITERIA

	WAIT	MO. TIME	C O M M A N D	1 2

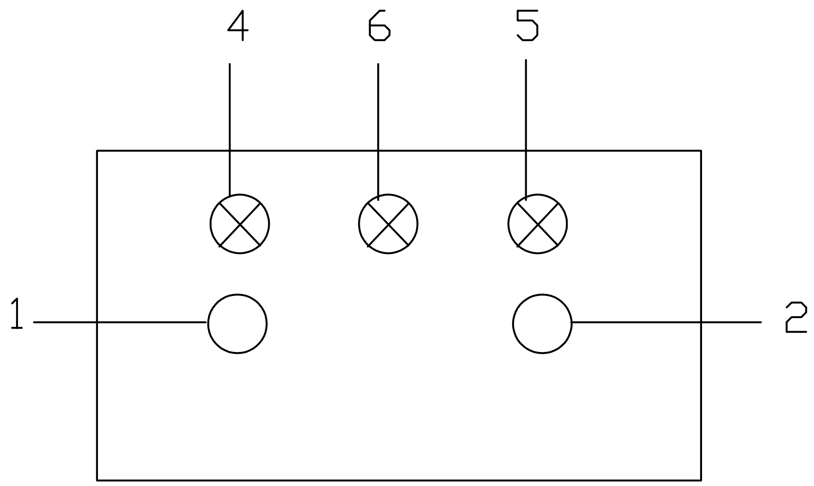
FIG. 2.2



1. CONTROL BUTTON MANUAL ON/OFF
2. INDICATION BUTTON 2 "SLC OFF"
3. INDICATION BUTTON 4 "SLC ON"
4. INDICATION BUTTON 3 "FAULT"

FIG. 3 SLC DISPLAY

FOR ELECTRIC MOTOR DRIVES, ACTUATORS
AND SOLENOID VALVES.



1. CONTROL BUTTON OFF (CLOSE)
2. CONTROL BUTTON ON (OPEN)
4. INDICATION BUTTON OFF (CLOSE)
5. INDICATION BUTTON ON (OPEN)
6. INDICATION BUTTON FAULT

FIG. 4.1 DRIVE INTERFACE DISPLAY

P	R	M	A	B		H	A	M	R	P
OFF/CLOSE							ON/OPEN			

FIG 4.2

FOR GRAPHICAL REPRESENTATION THE VARIOUS SIGNALS ARE HOOKED UP TO THE RESPECTIVE BOXES AS DESCRIBED.

P = PROTECTION COMMANDS
R = RELEASE SIGNAL
M = MANUAL COMMAND
A = AUTOMATIC COMMAND
} OFF/ON OR CLOSE/OPEN
B = BLOCK STATUS DISCREPANCY MONITOR
H = SELF-HOLDING (ONLY FOR ACTUATORS AND SOLENOID VALVES)

FOR INSTANCE ALL RELEASE OR ENABLING CRITERIA FOR THE OPERATION "ON" / "OPEN" WOULD BE HOOKED UP TO BOX R ON THE RIGHT HAND SIDE. ALL AUTOMATIC COMMANDS BEING RECEIVED BY THIS DRIVE INTERFACE. ARE HOOKED UP TO BOX A