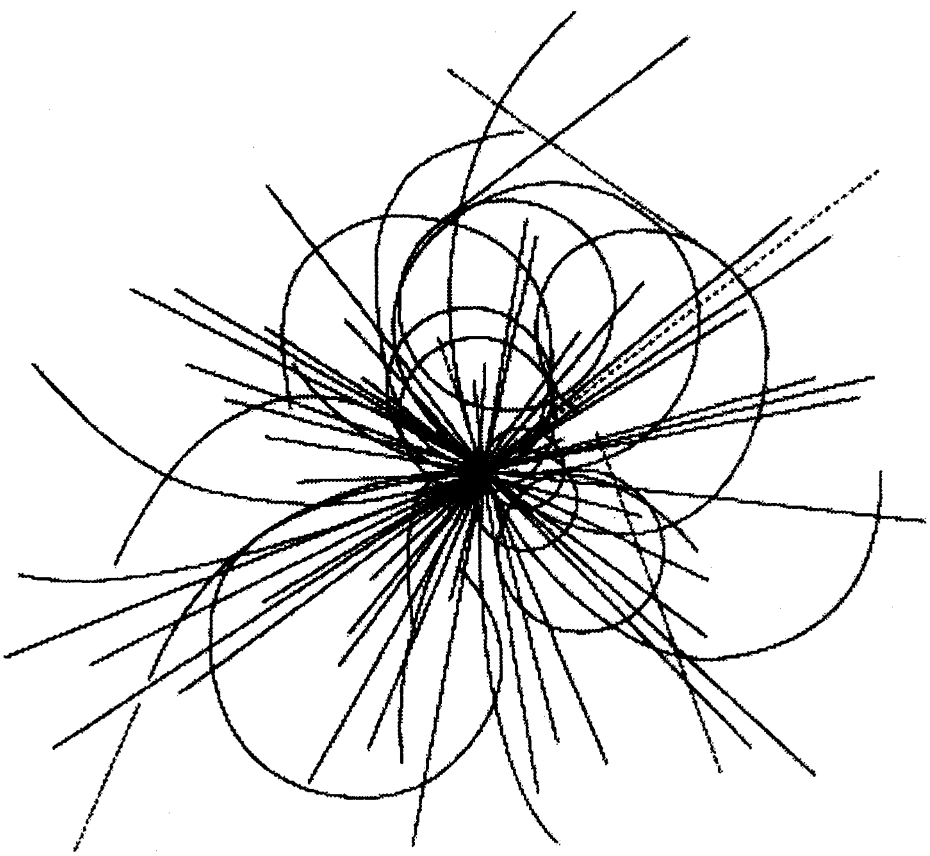
SSCL-Preprint-307

SSCL-Preprint-307
May 1993
Distribution Category: 400

R. Carcagno
V. Ganni

A Methodology to Describe Process Control Requirements



Superconducting Super Collider Laboratory

To be published in *Supercollider 5*

SSCL-Preprint-307

A Methodology to Describe Process Control Requirements*

R. Carcagno and V. Ganni

Superconducting Super Collider Laboratory†
2550 Beckleymeade Ave.
Dallas, TX 75237

May 1993

*Presented at the Fifth Annual International Symposium on the Super Collider, May 6–8, 1993 San Francisco, CA.
†Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

A METHODOLOGY TO DESCRIBE PROCESS CONTROL REQUIREMENTS

R. Carcagno, V. Ganni

Superconducting Super Collider Laboratory*
2550 Beckleymeade
Dallas, TX 75237, USA

ABSTRACT

This paper presents a methodology to describe process control requirements for helium refrigeration plants. The SSC requires a greater level of automation for its refrigeration plants than is common in the cryogenics industry, and traditional methods (e.g., written descriptions) used to describe process control requirements are not sufficient. The methodology presented in this paper employs tabular and graphic representations in addition to written descriptions. The resulting document constitutes a tool for efficient communication among the different people involved in the design, development, operation, and maintenance of the control system. The methodology is not limited to helium refrigeration plants, and can be applied to any process with similar requirements. The paper includes examples.

INTRODUCTION

The Cryogenics Department of the SSC Laboratory has decided to separate the selection and procurement of the computer control system from the procurement of the helium refrigeration plants needed for the project. The scope of supply for the cryogenic equipment vendor includes instrumentation (sensors, actuators) and wiring up to a well-defined interface, but does not include the computer control system needed to run the plant. A separate procurement will provide the computer control equipment and software necessary to run not only the refrigeration plants, but also all the underground cryogenic systems; these constitute 75% of the control system size as measured by the number of input/output points.

An important consequence of the decision to procure the computer control hardware and software separately is the need to define an efficient mechanism for communicating process control requirements between the vendor and the SSC. The methodology used must take into account the design goal of remote, unattended operation of these plants. Unfortunately, although several tools are available (e.g., binary logic diagrams[1] and sequential function charts[2]) there is no standard (such as P&IDs for piping and instrumentation) for defining process control requirements. Depending on the process, some tools work better than others, but in general a combination of tools is needed in order to completely describe the control requirements.

THE METHODOLOGY

In this paper we present a methodology that has been designed to capture and describe process control requirements for the collider helium refrigeration plants. These include monitoring, logic control, regulatory control, sequential control, and supervisory control. The plants must be configured to support the many operating modes of the collider[3], thus some features of batch control are also required.

The process control description document is the basis for the generation of software requirements specifications for the computer control system. The methodology is not limited to helium refrigeration plants, and can be applied to any process with similar requirements.

The methodology is based on a structured, top-down approach where object-oriented concepts are used. It is not concerned with any implementation features such as MANUAL or AUTOMATIC operating modes. The question of implementation is secondary to the process control description.

*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

The first task in this methodology is to identify the objects and their hierarchical relationships. The system is partitioned into a multilevel structure with each level containing a certain number of functionally modular parts (or objects). The objects should be more or less self-contained from the controls point of view. Ideally, objects communicate with each other exclusively via status words and commands. In practice, some process information (e.g., temperatures, pressures, flows, positions) must be exchanged as well. One of the goals of the object-oriented design is to minimize the amount of process information to be exchanged among objects.

A typical structure includes four levels. At the lowest level (Level 0), base-level objects are identified. Base-level objects are the principal building blocks and deal primarily with *devices* such as sensors, valves (on/off valves, control valves) and motors. Many objects at this level are found in a classic P&ID.

The next level (Level 1) contains a group of Level 1 objects associated with a *module* such as a compressor skid. Typical control functions of this level include regulatory control, sequential control, and process interlocks. Examples of Level 1 control functions are: a compressor skid shutdown sequence triggered by a high-high alarm in the motor winding temperature, and makeup flow regulation to the gas management module.

The next level (Level 2) contains a group of Level 2 objects associated with a *subsystem* such as a compressor group. Typical control functions of this level include supervisory control and equipment scheduling. Examples of Level 2 control functions are: automatic switching of 80 K beds and bed regeneration cycle scheduling, and coordinating compressor skid operation and gas management operation during plant startup.

The next level (Level 3) in the hierarchy of objects contains a group of Level 2 objects associated with a *system* such as a compressor system. Typical control functions of this level include system process management and process coordination with other systems (e.g., the refrigeration system). Examples of Level 3 control functions include configuring the compressor and refrigerator systems for minimum capacity mode.

Once the objects in each level and their relationships with upper level objects have been identified, a functional description of each object is needed. Four major concepts are used in this description: state, transition, function, and status words and commands. Four major tools are used to describe the concepts: the truth table, the sequential function chart, the state and transition diagram, and the cause and effect table.

ELEMENTS OF THE OBJECT FUNCTIONAL DESCRIPTION

An object state is associated with a given configuration of object components (e.g., a certain valve lineup is associated with the "ON" state). The major reason for defining a state is to provide a useful reference for the operator or for other objects.

Object states are described by the *truth table*. The truth table describes the status of subordinate control objects for each object state. In a truth table, row labels depict the subordinate objects, and column labels depict the state names. The matrix interstices indicate the subordinate object status. Devices under automatic control are designated with the name of the controlling loop. Analog devices not under automatic control are designated with the constant value at which they are positioned. A dash (-) indicates that the subordinate object status is not relevant to the state definition. Table 1 is an example.

Table 1. Example of truth table: Truth table for object – CMP-11.

SUBORDINATE OBJECT	ON	READY	OFF	LOCAL	SAFE
RMT-SWITCH	TRUE	TRUE	TRUE	FALSE	TRUE
EM-10102	ON	OFF	OFF	-	OFF
FV-10151	OPEN	OPEN	-	-	OPEN
FV-10152	OPEN	OPEN	-	-	OPEN
FV-10155	OPEN	OPEN	-	-	OPEN
FV-10156	OPEN	OPEN	-	-	OPEN
LV-10121-A	LC-10121	LC-101212	-	-	CLOSE
LV-10121-B	LC-10121	LC-101212	-	-	CLOSE
LV-10130	LC-10130	LC-10130	-	-	CLOSE
TIC-10103	AUTO	AUTO	-	AUTO	MANUAL
TY-10103	TIC-10103	TIC-10103	-	TIC-10103	CLOSE

An object transition is the sequence of events that must take place in order for the object to change from one state to another (e.g., open/close valves, turn motors on/off, put control loops in manual/auto).

Object transitions are described by a *sequential function chart* (SFC). An SFC is a graphical description of the transition according to the IEC 848 international standard[2]. Figure 1 is an example.

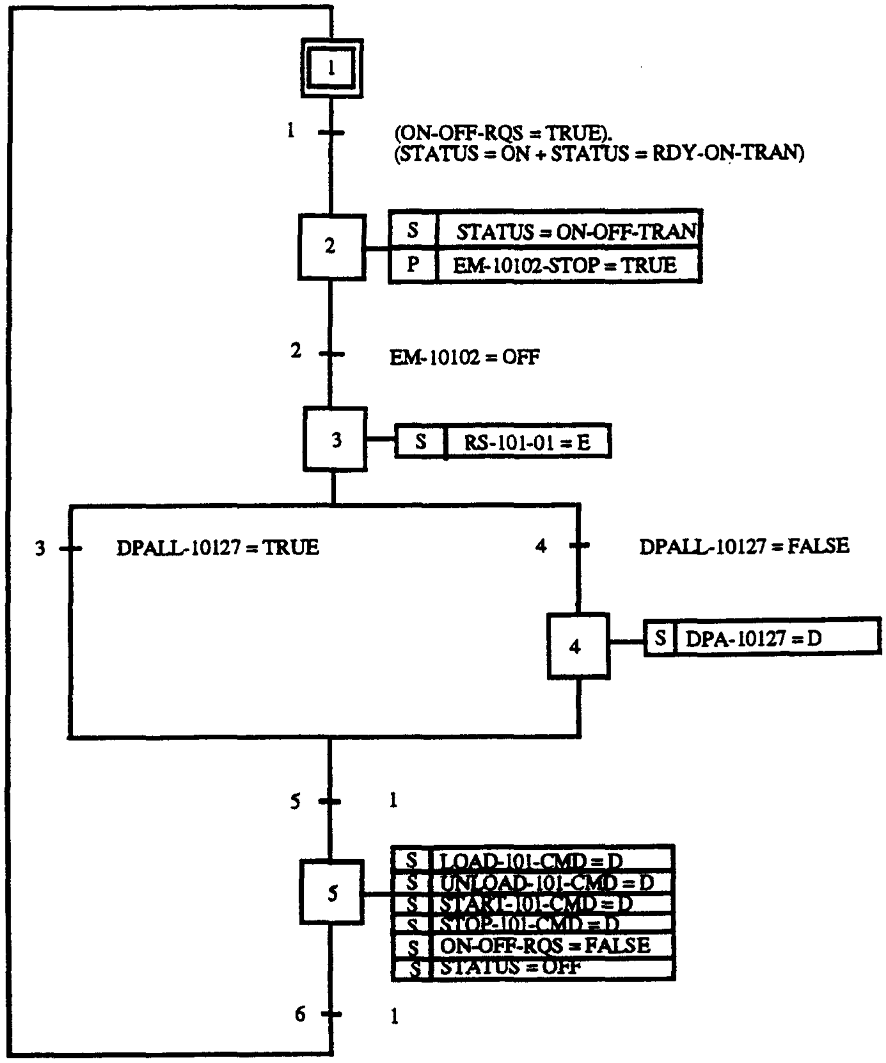


Figure 1. Example of a state and transition diagram.

The relationship between states and transitions is graphically described by the *state and transition diagram* (STD). Figure 2 is an example.

An object function is a piece of logic that the object executes either continually or sequentially in order to perform a certain control task (e.g., interlocks, alarms, PID loops, fill sequence). Functions may be enabled or disabled according to the object state.

Object functions are described by the *cause and effect table*. When functions are too complicated to be described by the cause and effect table, the table includes a reference to another graphic (e.g., binary logic diagrams, SFC) or tabular (e.g., PID table) representation. Table 2 is an example.

Table 2. Example of cause and effect table.

FUNCTION	TYPE	CAUSE			EFFECT		
		OBJECT	TAG	STATE	OBJECT	TAG	STATE
FU-101-03	CM	CMP-11	MMI-101-02	TRUE	CMP-11	ON-OFF-RQS	TRUE
SD-101-02	I	CMP-11	DPALL-10127	TRUE	CMP-11	ON-OFF-RQS	TRUE
SD-101-03	I	CMP-11	TAHH-10102	TRUE	CMP-11	ON-OFF-RQS	TRUE
ON-OFF-TRAN	SFC	CMP-11	ON-OFF-RQS	TRUE	CMP-11	*See Fig. 2*	

Status words and commands are the way objects communicate with each other. The status word is defined according to the object state, transition, or function taking place. There may be more than one status word per object (for example, a gas tank could be ON and PURE). Commands are generated by functions or by the operator. Status words and commands provide the basic linkage among the different tools used in the description.

For a more complete set of examples, see reference 4.

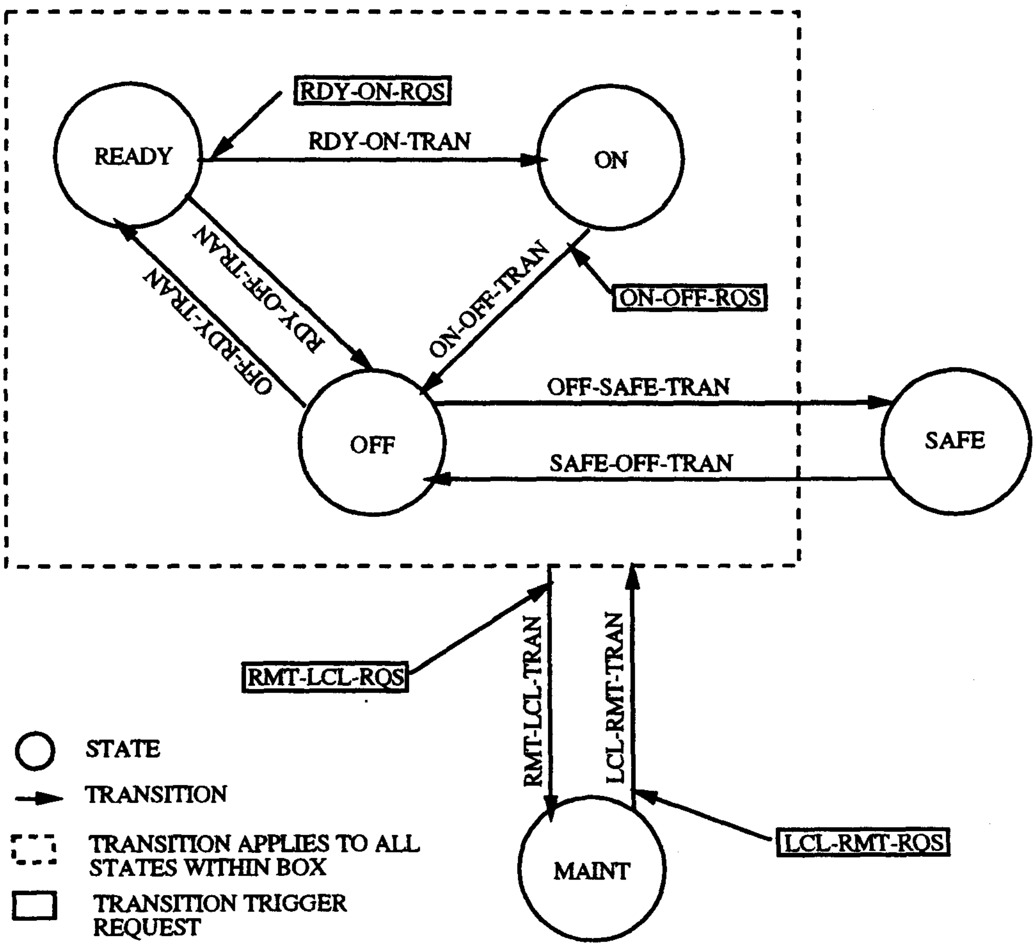


Figure 2. Example of a sequential function chart.

CONCLUSIONS

A well-defined standard for process control requirements description does not exist. In this paper we have presented a methodology designed to capture and describe process control requirements of the type expected in highly automated helium refrigeration plants. It is based on a structured, top-down approach where object-oriented concepts are used. We expect to use this methodology to facilitate the communication of process control requirements among refrigeration system vendors, control system vendors, and the SSCL.

REFERENCES

1. "Binary logic diagrams for process operations," ANSI/ISA S5.2-1976 (R1981). Instrument Society of America (ISA) publication (1981).
2. "Preparation of function charts for control systems," CEI/IEC 848: 1988. International Electrotechnical Commission (IEC) publication (1991).
3. R. Than, S. Abramovich, and V. Ganni, "The SSC cryogenic system design and operating modes," SSC Laboratory, SSC Cryo Note 92-12, October 1992.
4. R. Carcagno, V. Ganni, D. Rivenbark, and B. Shuster, "Process Control Description Example for a Compressor Skid," SSC Laboratory, SSC Cryo Note 92-13, October 1992.