Power Generation: A Non-Functional Subsystem

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Introduction

This paper endeavors to make clear the scope, breadth, diversity, and complexity of the power generation technical area insofar as Air Force interests are concerned. This will be done by presenting the non-functional character of power generation and the non-uniformity of specifying state-of-the-art. There follows an outlining of a means of categorization which encompasses power generation technology, functional subsystems and equipment, systems, and agencies influential upon power generation technology. A general approach to specifying power generation State of Technology will be suggested from the categorization.

Summary

Power generation, as opposed to functional equipment, performs no function in or of itself to fulfill system mission tasks. It exists only to fulfill the needs of functional equipment for power. The many potential users of power, and the fact that each usually has interests different from any other for their particular power needs leads to complications in meeting those needs. This complication arises, in part, from a lack in the means of adequately reporting the state-of-the-art and the power needs. Resolving the state-of-the art issue and providing a means of categorization whereby a meaningful state of technology can be defined will reduce considerably the problem of developing power generation subsystems to meet the needs of functional equipment and systems.

Definitions

There are several terms that need defining for purposes of clarity in the following discussion. These power generation - oriented definitions are somewhat liberal interpretations of corresponding definitions presented in Air Force Manual 11-1. These terms with definitions are the following:

Power Generation Technical Area

The power generation technical area encompasses all energy conversion and power technology necessary for the operation of ground, aeronautical, missile, space, and electronic systems, exclusive of primary propulsion but including electric power for electric propulsion. The power generation technical area provides the integrated power technology needed by functional subsystems and equipment incorporated into systems.

Functional Subsystem and Equipment

The functional subsystems and equipment encompasses all devices, equipments, and techniques other than power generation that are necessary to achieve a system. These subsystems and equipment perform those functional operations necessary for a system to accomplish a defined task or mission. Examples of several diversified functional subsystems include but are not limited to; Fire Control, Guidance, Surveillance, Life Support, etc. Generally throughout the discussion, equipment or subsystems will be used in place of the term functional subsystems and equipment.

System

An integrated relationship of all subsystems, and equipment, all aligned to establish proper functional continuity towards the successful performance of a defined task or tasks. The support personnel associated with systems were not included in the definition, since herein we are primarily concerned with equipment. Systems can be relatively simple or as complex as a variety of air planes, communication and surveillance networks, and types of missiles which work together in a coordinated effort in accomplishing a defined task or mission such as defense against enemy strategic weapons.

Agency

Any industrial, educational or government organization that has an influence upon power generation, functional subsystems and equipment or systems technology.

State of Technology

The State of Technology is a well defined and organized setting forth of technical facts and value considerations concerning a subject in a frame of reference (usually parametric) which recognizes the totality of users of the information and those users' needs. The users' predominant need shall be taken to be: a basis for making decisions involving the potential utility and applicability of the subject as a function of time and resources.

Non-Functional Power Generation

Power generation is unique in that it is non-functional. As opposed to functional equipment, it performs no function in or of itself to fulfill system mission operational requirements. Power subsystems, therefore, do not relate to only a single function but must provide all of the power required by the large variety of equipment which compose a system. Consequently, it can be said that power subsystems exist only to fulfill the needs of functional equipment for power. The fulfillment of these needs, however, must be accomplished within severe constraints. Ideally the power subsystem must have zero weight, complete simplicity, excellent reliability, and be readily available. Realistically the constraints are not peculiar to individual and separate cases but must guide all power generation research programs.

From a systems design standpoint, the constraint placed on power generation is that it must provide power to meet the integrated, diverse needs of many equipments integrated into a system. This involves the analysis and integration of these equipments as they relate to the total system and then the definition of the system power profile with design specifications for the power generation subsystem.

The fact that there are certain specific equipments which have singular and unique power needs places a constraint on the ability to fulfill those needs in a timely and effective manner. Equipments such as electric propulsion and LASERS which require power characteristics generally not covered by Mil-Specs are representative of these unique power needs.

The technological programs which involve power generation development must be timed such that they will properly complement the development programs in functional equipment and systems. This fact in addition to governed resources impose constraints upon the timely acquisition of power generation technology.

In addition to the aforementioned constraints, there are parametric performance limits which must be achieved and maintained. These relate to power level, size, weight, environmental response, life and reliability, flexibility, etc. The degree to which each parametric constraint affects the power generation subsystem will vary with equipments but generally each is of vital importance with regard to an overall system point of view.

In planning development programs which will provide capabilities that will fulfill future systems requirements, the constraints must be analyzed and followed as guides to assure worthwhile programs. This is a complicated task because of the non-functionality of power and is made ever more difficult by the rapidly increasing complex of subsystem and system technologies.

The expanding complex of system and subsystem technologies has contributed to a prevailing lack of understanding of the influence of power generation on equipment designs. Power generation being "non-functional" cannot be considered in the same frame of reference as functional equipment from an over-all system design point of view. Power generation cannot be ignored while concern is wholly devoted to other equipment of the system. This philosophy results in compromises of the system's mission and/or performance. Power requirements must be considered coincident with the functional equipment and integrated towards a power subsystem concept on a continuous basis.

Designers of advanced subsystems and systems usually strive for increased performance, flexibility and better cost effectiveness. For these improvements to be realized requires that planners and designers first become aware of the effect that power generation has on the total system. Secondly, designers must react to effectively integrate the significant factors of power generation with the total system design in its earliest phases to prevent compromises in overall performance. It is equally important that agencies engaged in power generation technological work, become more functional equipment and systems application conscious. Then they can react to supply the information needed to define the technological state and future potential of their efforts in a frame of reference useful to subsystems and systems applications.

If through this paper, agencies engaged in power generation work become aware of the scope, breadth, diversity, and complexity of the power generation technical area and a realization of the need for greater emphasis on power generation throughout the early stages of system design is provided then the paper will have accomplished much of its objective.

State of the Art Issue

The prime objective of the power generation technical area is to fulfill the power needs of functional equipment of systems. While this is a reasonable objective, it is incomplete, in the extreme, as an indication of the complexity and magnitude of the problem.

An agency engaged in power generation research publishes data pertaining to the performance of a specific concept under investigation. Parametric data such as efficiency, weight, size, temperature, rpm, etc. are presented and it indicated that the data may be taken as representing the state-of-the-art for the concept. While it is quite true that this is, to a certain degree, the state-of-the-art, usually the information must be used with care and judgment because it is not associated with or related to an explicit state of technology.

There is a vagueness, flexibility and individuality of interpretation which surrounds the term "State-of-the-Art". It really cannot be defined without relating to some sensible base. For instance, there is a state-of-the-art progression beginning with the initial conceived idea up through the tested, applied and proven final product.

These stated issues regarding state-of-the-art definition can cause a great deal of difficulty for some agencies relatively unfamiliar with the area of technology. As an example, an agency which is involved in the development of subsystems or systems can easily be lead into thinking that a "reported state-of-the-art" can be applied to a subsystem or system under consideration when, however, the "reported state-of-the-art" may be representative of a laboratory device which possibly is many years and design changes away from a usable device.

In the past, the trend has seemingly been that no two agencies use identical testing procedures in determining concept performance data. Usually the data is taken at different points of temperature, environment, rpm, power level, voltage, current, etc. which makes it very difficult to correlate data from two different agencies for near accurate determination of concept capability. This can lead to the necessity for the systems developer to sponsor a comprehensive test program to establish the concept capability before he can apply it to his system.

The task of sorting, correlating, analyzing and assembling meaningful data from the large amount of information generated by the many agencies involved in power generation technology is immense. State-of-the-art reports have nobly attacked the problem in the past and for many purposes have been very successful. However, a total solution providing up to date information on an equitable and organized basis has not been achieved.

It is toward the alleviation of this issue, that organized thinking must be applied. As stated in the introduction, an approach to this point is a categorization of power generation technology, functional subsystems and equipment, systems, and agencies influential upon power generation technology and subsequently applying this categorization, in suggesting an approach toward specifying a power generation State of Technology.

The term "State of Technology" has been adopted by the authors in place of the term "State-of-the-Art". It is their hope that the presentation of this subject matter will evolve into a method that can be used in the future for reporting power generation technological states. Since the term state-of-the-art has been used for a variety of purposes in the past, it is the authors' desire to dissociate from the term altogether and use a new terminology for their suggested approach. These remarks are not to be taken as critical of state-of-the-art reports or indicative that these reports have not had significant value.

Categorization

It has been common practice when dealing with power generation technology to make certain divisions and subdivisions which tend to simplify or clarify the technical area. This divisioning usually segregates the energy sources (solar, nuclear, or chemical), energy conversion methods (static or dynamic), power conversion method, and conditioning and transmission components. Such divisions and subdivisions are made mandatory by the breadth and diversity of the area; but this subdividing is usually inadequate for dealing with the power generation technical area in such instances as state of technology reports.

The categories of technology arrived at in our activities to date, suggests that herein lies the potential for a well organized, general approach to specifying the power generation state of technology. Further, it appears that within this approach there is potential for maximizing the value of state of technology reports for users of the reports.

A generalized representation of the categorization arrived at is shown in figure 1. Each category is interrelated with the technologies and agencies as depicted by the arrows. A more detailed explanation by technology follows which expands each category to better show the breadth, diversity, and complexity of the power generation technical area and its relationship to functional equipment, systems, and agencies.

Power Generation Technology

The categories of power generation technology are shown in figure 2. Within each category there are particular divisions which are necessary for identifying a state of technology. For instance, research and the four development levels listed under level. Each of these levels are representative of a technology, at some point in time from its initial conceived idea to an operational device. Since these levels play an important role in forming a base to which the technology can be related, an understanding of each is necessary.

Research can be defined as an effort directed toward an increase in fundamental knowledge. In power technology, this could be the application of theory to obtain the ground work for a new energy converter. The parameters of interest are very general and of a phenomenalogical nature.

Exploratory development is the next step after research. It is generally defined as those efforts directed toward the solution of specific problems, short of major development projects. This type of effort may vary from the application of the results of research to accomplish specific objectives, which may be fairly fundamental, to quite sophisticated bread-board hardware, study, programming and planning efforts. It would thus include studies, investigations, and minor development effort. The dominant characteristic of this type of effort is that it be pointed toward specific military problem areas with a view toward developing and evaluating the feasibility and practicability of proposed solutions and determining their parameters. These parameters are more specific and more inclusive than those in research. Some of the parameters of interest are; specific weight, specific size, resistance to hostile environments, temperature limitations, costs, power characteristics, life and reliability, and flexibility of applying the technology.

Advanced development succeeds exploratory development and includes those efforts directed toward the building of test or experimental hardware. The parameters of interest here are similar to those in exploratory development but are not as inclusive because much parametric data is established in earlier states.

Engineering development includes those development programs being engineered for actual use but which have not yet been approved for procurement or operations. This is a product improvement type of effort oriented toward actual application.

Operational development and operational terms are fairly straight forward. They include the actual acquiring and development of an operational subsystem to the attainment of the capability to perform its intended task.

In addition to level, categories of scope, type, and discipline are shown for power generation technology. The scope indicates to what degree the various levels of technology have progressed toward an operational or systems application whereas type designates the system to which the technology applies. The divisions for each category represent, for the most part, that necessary for purposes of defining the state of technology. The technique in which this might be accomplished will be suggested later.

Functional Equipment Technology

Except for the divisions under the category of disciplines, the functional equipment categorization as shown in figure 3 is similar to the categorization of power generation technology. The discipline category identifies the individual technical areas within the total technology.

Systems Categorization

The categorization for systems as shown in figure 4 is judged to be essentially self-explanatory to the average technical layman and will not be dealt with in any detail here. The main point of emphasis is that under each category there are significant divisions which play a vital role in helping to define the state of technology for power generation.

Agencies Categorization

Categories of some of the organizations that may have influence upon power generation, function subsystems and systems are listed in figure 5. There are several hundred national agencies, other than government, that have significant influence upon the technologies presented herein. It would be quite an involved task to subdivide each of the scope categories, however, the Department of Defense scope is subdivided in a limited fashion to show some of the influential agencies. A point worth making regarding the category of position is that an agency can influence power generation without holding a contract in the area. From association with other agencies and from within their own activities, an agency can make observations and use such to bring influence to bear on the power generation technical area. We in the Aero Propulsion Laboratory are always receptive to technically sound suggestions, ideas, and recommendations pertaining to power generation technology advancement.

State of Technology Specification

The preceding discussion has dealt with the non-functionality of power generation, the state-of-the-art issue, and a means of categorization. Also, the breadth, diversity, and complexity of power generation has been indicated. A general approach to specifying power generation "State of Technology" from the categorization can now be suggested.

Attention should be directed to the definition of State of Technology as presented earlier and especially to the points of recognizing the totality of users of the information and the frame of reference in which the subject is presented.

The approach could and possibly should begin with the divisions of power generation technology which segregates the area by energy source and conversion method. An alternative would be to segregate the energy limited concepts from the power limited concepts. With this division, each subject can then be considered in terms of the "level" categories with parameters characteristic of and meaningful within each level. An integration of the appropriate categories for associated technologies and agencies is required to construct the appropriate frames of reference and establish the totality of users of the information. One might visualize this as a multi-dimensional matrix with interacting and related categories and sub-categories. The scope of efforts relate to each level and form the base for the characteristic parameters used in the state of technology report. Therefore, the scope must always be included in the report. Each of the categories of functional equipment, systems and agencies to which the subject applies and for which it fulfills a need should be clearly specified. Particularly, this specification should be included when it would be significant to systems designers and functional equipment developers.

The reported State of Technology, therefore, should include and relate to one or more of the categories for each of the associated technologies. The data should be well organized technical facts and/or value considerations. If this approach is followed, the state-of-the-art issue will be essentially resolved, and a meaningful method of reporting states and trends of technology can result.

CATEGORIES

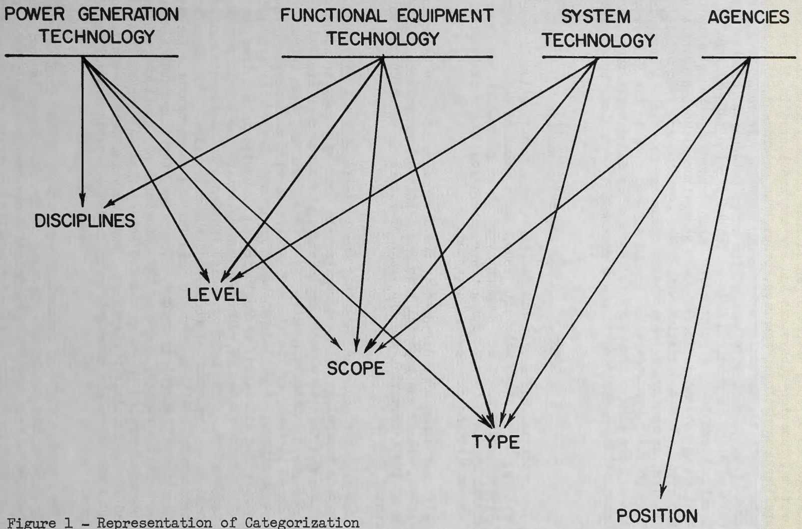

Figure 1 - Representation of Categorization

CATEGORIES OF POWER GENERATION TECHNOLOGY

LEVEL	SCOPE	TYPE	DISCIPLINE: SCIENTIFIC	DISCIPLINE: ENGINEERING
RESEARCH	COMPONENT	AIRCRAFT	Electrochemistry	Electrical
EXPLORATORY DEVELOPMENT	INTEGRATED COMPONENT	AEROSPACE	Thermionics	Mechanical
ADVANCED DEVELOPMENT	SUBSYSTEM	MISSILE	Thermoelectricity	Nuclear
ENGINEERING DEVELOPMENT	INTEGRATED SUBSYSTEM	SPACE	Photovoltaics	Astronautical
OPERATIONAL DEVELOPMENT		GROUND	Fluid Dynamics	
OPERATIONAL			Power Conversion	
			Power Control	
			Power Transmission	
			Energy Exchangers	
			Heat Exchangers	
			Energy Source	
			Energy Conversion	

Figure 2 - Categories of Power Generation Technology

CATEGORIES OF FUNCTIONAL EQUIPMENT TECHNOLOGY

LEVEL	SCOPE	TYPE	DISCIPLINE: SCIENTIFIC	DISCIPLINE: ENGINEERING
RESEARCH	COMPONENT	AIRCRAFT	Attitude Control	Electrical
EXPLORATORY DEVELOPMENT	INTEGRATED COMPONENT	AEROSPACE	Communications	Mechanical
ADVANCED DEVELOPMENT	SUBSYSTEM	MISSILE	Countermeasures	Nuclear
ENGINEERING DEVELOPMENT	INTEGRATED SUBSYSTEM	SPACE	Detection	Astronautical
OPERATIONAL DEVELOPMENT		GROUND	Data Management	
			Electric Propulsion	
			Environmental Control	
			Fire Control	
			Guidance & Navigation	
			Life Support	
			Power Control	
			Power Conversion	
			Power Transmission	
			Surveillance	

Figure 3 - Categories of Functional Equipment

CATEGORIES OF SYSTEMS

LEVEL

- GENERAL OPERATIONAL REQUIREMENT
- SYSTEM STUDY REQUIREMENT
- SYSTEM REQUIREMENT
- DEFINITION PHASE
- ACQUISITION
- OPERATIONAL

SCOPE

- SYSTEM
- INTEGRATED SYSTEM

TYPE

OFFENSIVE DEFENSIVE OFFENSIVE/DEFENSIVE

- ELECTRONIC
- AIRCRAFT
- AEROSPACE
- MISSILE
- SPACE
- GROUND

Figure 4 - Categories of Systems

CATEGORIES OF AGENCIES

SCOPE

- DEPARTMENT OF DEFENSE
  - ARMY
  - ARPA
  - NAVY
  - AIR FORCE
    - AFSC DIVISIONS & LABS
    - AF CENTERS
    - AF RESEARCH LABS
- AEC
- NASA
- INDUSTRIAL
- EDUCATIONAL

TYPE

- NATIONAL
- INTERNATIONAL
- RELATED TO TECHNOLOGY
- NON-RELATED TO TECHNOLOGY
- PROFIT
- NON-PROFIT

POSITION

- SPONSORED R&D
- NON-SPONSORED R&D

Figure 5 - Categories of Agencies