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Monitoring New Technological Developments in the Electricity Industry : An International Perspective

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Monitoring New Technological Developments in the Electricity Industry : An International Perspective

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Résumé / Abstract

Être capable de surveiller et d'évaluer les développements technologiques constitue une activité essentielle pour une industrie appelée à être de plus en plus active dans toutes les régions du monde et dans les marchés qui exigent un registre de configurations technologiques étendu. Cet article expose l'approche méthodologique employée pour surveiller les nouveaux développements technologiques dans l'industrie de l'électricité et dévoile les résultats d'une enquête DELPHI menée parmi un groupe d'experts internationaux.

Being able to monitor and asses technological developments represents an essential activity for an industry expected to be increasingly active in all of the regions of the world and in markets which require a wide array of differing technological configurations. This paper outlines the methodological approach used to monitor new technological developments in the electricity industry and presents the results of a DELPHI survey conducted among a panel of international experts.

Mots Clés : Surveillance technologique, industrie électrique, DELPHI

Keywords : Technological Monitoring, Electricity Industry, DELPHI

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1. INTRODUCTION

The electricity industry is undergoing tremendous changes as a result of numerous worldwide pressures. Colossal demands for new additions and modernization in the field of electricity generation as well as in the transmission and distribution sector are originating from industrializing and developing countries. At the same time, privatization is making increasing inroads in the vast majority of countries while the industry is also faced with the challenges of deregulation and freewheeling competition. Furthermore, growing environmental conciousness and increased awareness of energy efficiency programs are discernible trends in industrialized countries but are also becoming more and more of an issue in many industrializing countries.

With all these combined and sometimes conflicting pressures, the electricity industry faces an uncertain future [1]. In such a context, new technological developments assume a greater importance and monitoring these developments becomes more difficult than before. It is therefore felt that an attempt to identify and evaluate technologies with significant potential for the electricity industry as a whole would be of interest. This paper reports on such an attempt and presents the results of the first phase of a longitudinal study which will be carried on annually over the next few years.

2. METHODOLOGY

The identification and assessment of significant technologies in terms of their potential impact on the whole of the industry requires a strict methodology [2]. The study was conducted in three distinct and consecutive steps (figure 1).

[Figure 1]

Step I: Thorough review of existing documents

A broad and detailed search was done of the specialized journals such as *Electrical World, Power, Water Power and Dam Construction, Hydrovision, Transmission and Distribution, IEEE Transactions on Power Delivery*, of scientific data bases in the fields of engineering and applied sciences such as Compendex Plus and Inspec, and of all publicity available reports from major research centres or institutes such as the research center of the Kansai Electric Power Co. Inc. in Japan or the EPRI (Electric Power Research Institute) in the U.S.A.. Close to 10,000 documents were analyzed, compared and synthesized by a group of experts and graduate students active in the field. This information – a considerable amount – was then filtered and structured in order to obtain a preliminary list of new technological developments.

Step II: Identification of new technological developments

The preliminary list of new technological developments (step I) was submitted for critical analysis to 45 carefully selected R&D experts from different fields. These experts, from organizations such as ABB, the Canadian Electrical Association, the National Research Council of Canada, Atomic Energy of Canada, EDF-DER (Électricité de France - Direction des études de recherche) and IREQ (Institut de recherche d'Hydro-Québec), provided the vital input for validating the final list of new technological developments.

This final list comprised 115 technologies, which were classified into the following five broad areas of activity:

(i) generation
(ii) transmission and distribution
(iii) protection, control and energy management systems
(iv) efficient use and management of electricity
(v) installation and maintenance of equipment

Two major observations concerning this final list have to be made. First, all the new technological developments are *active*, meaning that research groups are still working on developing and improving these technologies. In some cases, these are well-known existing technologies to which improvements are being made through various R&D efforts. Second, they essentially reflect a *technology push* perspective as opposed to a *market pull* perspective.

Step III: Assessment of the new technologies' potential

The potential of the 115 new technological developments was then assessed by the panel of international experts using the DELPHI technique. This technique is basically a special type of survey that ensures complete confidentiality and anonymity by providing only a global statistical response and allowing controlled feedback from the respondents [3].

The choice of respondents is clearly critical in this third and last step. Forty experts from Asia, Europe and North America were chosen based on their credibility, experience and knowledge in their respective fields of research and were in all cases different from the 45 experts who validated during the second step of the project the final list of new technological developments. All experts were advised by telephone that they were participating in a DELPHI survey aimed at uncovering significant trends in technological developments in the industry and the procedures to be followed were explained. Twenty-nine of the experts contacted agreed to fill out the questionnaire, which required two to three hours of work on their part. The resulting response rate of 72.5% was considered very satisfactory. Participants in the DELPHI survey came from all regions and were affiliated with both public and private sector organizations such as the World Bank, EDF, ENEL, EPRI, ENDESA, IEA, Central Research Institute of Electric Power Industries (Tokyo), Tokyo Electric Power Co., Kansaï Electric Power Co., ABB Carbon AB, New York Power Authority, Hydro-Québec, and BC Hydro as well as a number of universities.

The respondents provided the following information for each of the 115 technologies:

- the future importance of the technology
- the year when the technology would be used at a significant level (1997, 2000, 2005, 2010+, or never)
- the level of knowledge the expert felt he/she held with respect to the particular technology

This last point represents a scale of self-ranked expertise and is particularly important since it allowed us to weight the experts' answers taking into account each one's level of expertise with respect to each of the 115 technologies.

3. MAIN FINDINGS

The results of the DELPHI survey are presented in tables 1, 2, 3 and 4.

3.1 Technologies with the highest potential for all areas of activity

The 25 most important technologies, in decreasing order based on the average score given by the 29 experts, along with their time horizon, are presented in table 1.

[Table 1]

This table highlights a number of interesting points:

- the 25 most important technologies all come from three areas of activity of operations related to (i) protection, control and energy management systems, (ii) efficient use and management of electricity, and (iii) equipment installation and maintenance;

- one notes the almost universal use of information technologies (telecommunications, software and artificial intelligence) and the importance of fibre optics and new materials;

- the time horizon for widespread use of these technologies is relatively short (by the year 2000, in general) with the exception of automatic current limiters using superconducting technology for network protection.

3.2 Technologies with the highest potential in the fields of generation and transmission / distribution

As none of the 25 most important technologies are related to the first two broad areas of activity, let us turn to the technologies that are potentially the most important for activities related to the generation (table 2) and transmission and distribution (table 3) of electrical energy. Based on the results presented in these two tables, environmental considerations and the integration of new materials seem to be the main trends.

[Tables 2 and 3]

3.3 Technologies with the lowest potential for all areas of activity

The ten technologies with the lowest potential are listed in table 4. We should note that the time horizon for implementing these technologies is either long (the year 2010 or later) or quite uncertain.

[Table 4]

3.4 Validity and reliability of the DELPHI survey results

It proved possible to reach a consensus in the very first round. Based on statistical tests, the 29 experts were in almost complete agreement on the 25 most promising technologies (table 1) and the reliability among experts is excellent (inter-rater reliability = 0.92). On the other hand, in the case of the ten technologies with the lowest potential (table 4), the reliability of the results is somewhat lower but still completely acceptable (inter-rater reliability = 0.71).

4. CONCLUSION

Results of the DELPHI survey tend to indicate that an important shift is taking place in the industry. Many of the most significant technologies with the potential for a real impact on the marketplace are related to information technologies and intelligent systems. As in other industries where information management has become a core competence, it is felt that gradually, the whole electricity industry will be confronted with ever-increasing customer requirements, forcing the major players to consider themselves as providers of "services" rather than "hard products". In such a scenario, both ends of the value chain presented in figure 2 take on a strategic dimension when compared to what was going on previously in the industry. First, being at the forefront of customer needs and expectations for low-cost, high-quality services will create mounting pressures for new technological developments at the interface of the customer-supplier relation. Second, scanning and assessing technological developments represent an essential acitvity for an industry expected to be increasingly active in all of the regions of the world and in markets which require a wide array of differing technological configurations. Thus, the real challenge for most energy product or service providers is to thrive at offering the appropriate portfolio of technology/market options for the different market segments around the world taking account the time horizon for the significant use of a particular set or subset of technologies.

[Figure 2]

The very dynamic nature of this global industry, along with the real market opportunities with which it is confronted, requires continuous monitoring of technological developments, especially when one considers the significant impacts of these developments on the generation, transmission and distribution of electrical energy around the world. These reasons have prompted us to formalize the DELPHI survey into a recurring annual activity.

Notes

1. Forecasting energy developments, especially in the electricity industry is fraught with considerable uncertainty according to several authors (see for example Richard J. Eden, "World Energy to 2050: Outline Scenarios for Energy and Electricity", Energy Policy, Vol. 21, No. 3, march, 1993, pp. 231-237).

2. The methodological techniques used for monitoring new technological developments are discussed in greater details in Alan L. Porter, A. Thomas Roper, Thomas W. Mason, Frederick A. Rossini and Jerry Banks, Forecasting and Management of Technology, John Wiley and Sons Inc., New York, 1991.

3. The DELPHI survey is used by the University of Michigan as a comprehensive benchmark of technological and commercial developments for the automotive industry.

Biographical notes

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Table 1
Results obtained from the DELPHI survey: the 25 technologies with the highest potential and their time horizon

	Technologies with the highest potential in decreasing order	Time horizon[1]
1.	Simulation software for network design planning – integrated planning tools	2000
2.	Adaptative controls and protection – system telecommand	2000
3.	Intelligent autodiagnostic functions on equipment – artificial intelligence	2000
4.	Load control – automatic control by residential or industrial users	2005
5.	Transport and distribution network automation – system telecommand	2005
6.	Fibre optic sensors – equipment protection	2000
7.	Computerized diagnostic tools (with signature analysis)	2000
8.	Fibre optic networks – telemonitoring system	2005
9.	Network security – decision support systems	2000
10.	Simulation software for plant and network performance predictions – integrated planning tools	2000
11.	Fault and alarm analysis – diagnostic tools	1997
12.	Power station automation – system telecommand	1997
13.	Electronic metering of different consumption indicators – consumption management	2000
14.	Electronic circuit-breakers	2000
15.	Network optimization – decision support systems	2000
16.	Simulation software for environmental management – integrated planning tools	2000
17.	New services offered to users of the information superhighway	1997
18.	Telemetering using fibre optic networks for residential users – technologies for consumption management	2000
19.	Simulation software for equipment planning – integrated planning tools	2000

Table 1 (suite)
Results obtained from the DELPHI survey: the 25 technologies with the highest potential and their time horizon

Technologies with the highest potential in decreasing order		Time horizon[1]
20.	Simulation software for control system and instrument validation – integrated planning tools	1997
21.	Lightning arresters – Zn-0 with polymeric envelope	1997
22.	Intelligent management system for maintenance groups – technologies that facilitate installation and maintenance of equipment	2000
23.	Electronic current limiters – network protection	2000
24.	Fibre optic network – user communication	2000
25.	Automatic current limiters using superconducting technology – network protection	2010 +

Source: Data files – École Polytechnique, DELPHI survey

[1] Indicates the year when the technology will be used to a significantly extent

Table 2
Results obtained from the DELPHI survey: Technologies with the highest potential for electricity generation and their time horizon

	Technologies with highest potential	Time horizon[1]
1.	High-efficiency turbines (temperature > 1,300° C) – gas-turbine generating station	1997
2.	Photovoltaic power stations – solar stations	2005
3.	Advanced wind-turbine generating stations	2000
4.	Superconducting magnetic energy storage	2010 +
5.	Fluidized bed coal combustion – thermal generating stations	2000

Source: Data files – École Polytechnique, DELPHI survey

[1] Indicates the year when the technology will be used to a significantly extent

Table 3
Results obtained from the DELPHI survey: Technologies with the highest potential for the transmission and distribution of electrical energy and their time horizon

	Technologies with the highest potential	Time horizon[1]
1.	Static series capacitors (static regulators – TCSC)	2000
2.	Composite isolators	2000
3.	Dry underground wires	1997
4.	Power controllers using passive components – reactors and capacitors (FACTS)	1997

Source: Data files – École Polytechnique, DELPHI survey

[1] Indicates the year when the technology will be used to a significantly extent

Table 4
Results obtained from the DELPHI survey: The 10 technologies with the lowest potential and their time horizon

	Technologies with the lowest potential[1]	Time horizon[2]
1.	Modular high temperature gas reactors – nuclear generating stations	Never
2.	Advanced liquid metal reactors – nuclear generating stations	Never
3.	Thermal generating stations using Kalina cycles	2010 +
4.	Non-conventional fuel storage – upstream energy storage systems	2010 +
5.	Storing CO_2 in empty gas wells – non-polluting systems	2010 +
6.	Poles in glued wood strips – distribution	2000
7.	Residential geothermal energy – downstream generating technologies	Never
8.	Magnetohydrodynamic power generation – thermal generating stations	2010 +
9.	Fast breeder reactors – nuclear generating stations	2010 and +
10.	Compressed-air energy storage (CAES) – upstream energy storage systems	2010 and +

Source: Data files – École Polytechnique, DELPHI survey

[1] In increasing order of importance starting with the technology with the lowest potential

[2] Indicates the year when the technology will be used to a significantly extent

Figure 1
Technological monitoring for the electricity industry: Methodological procedure

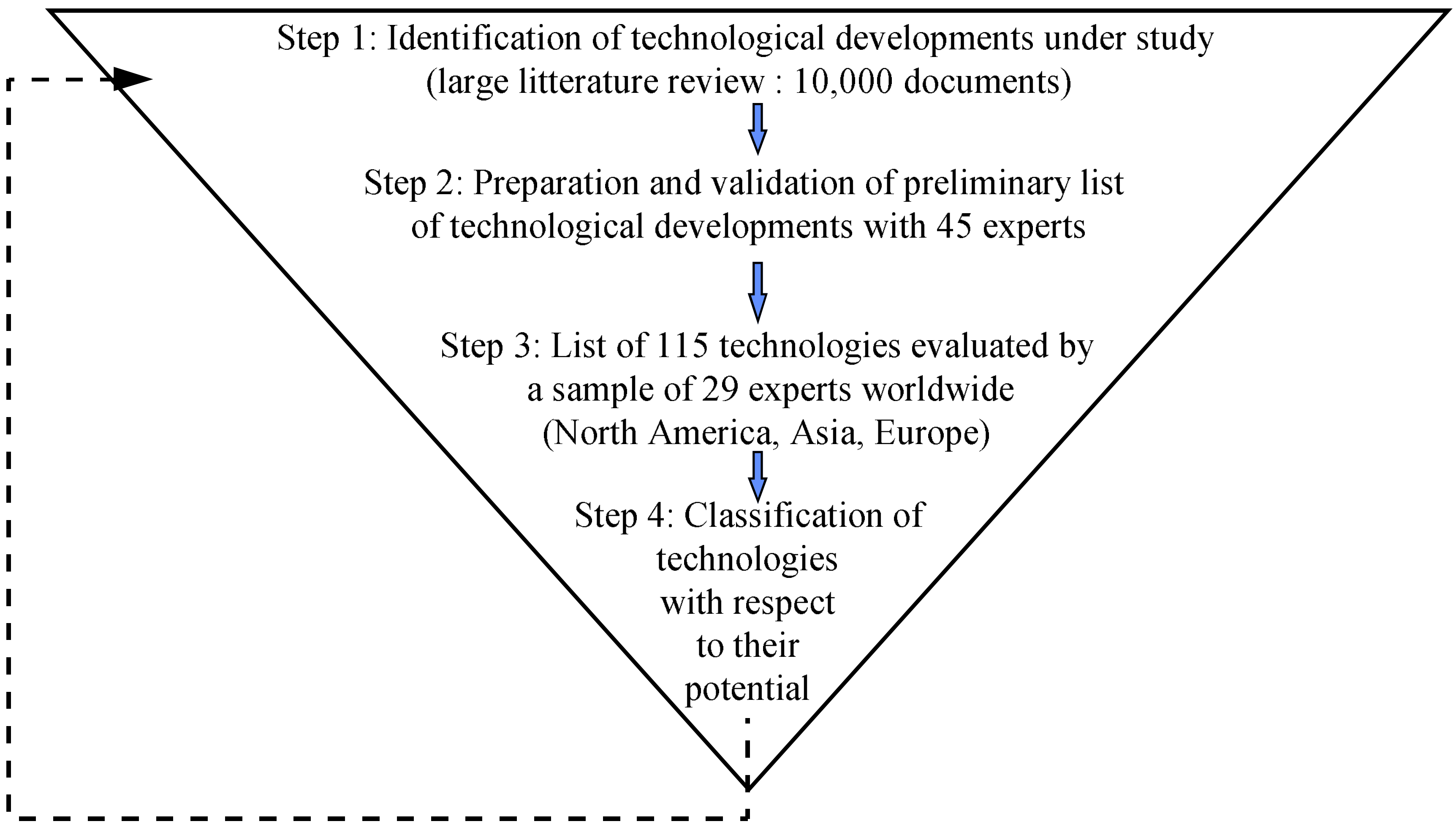
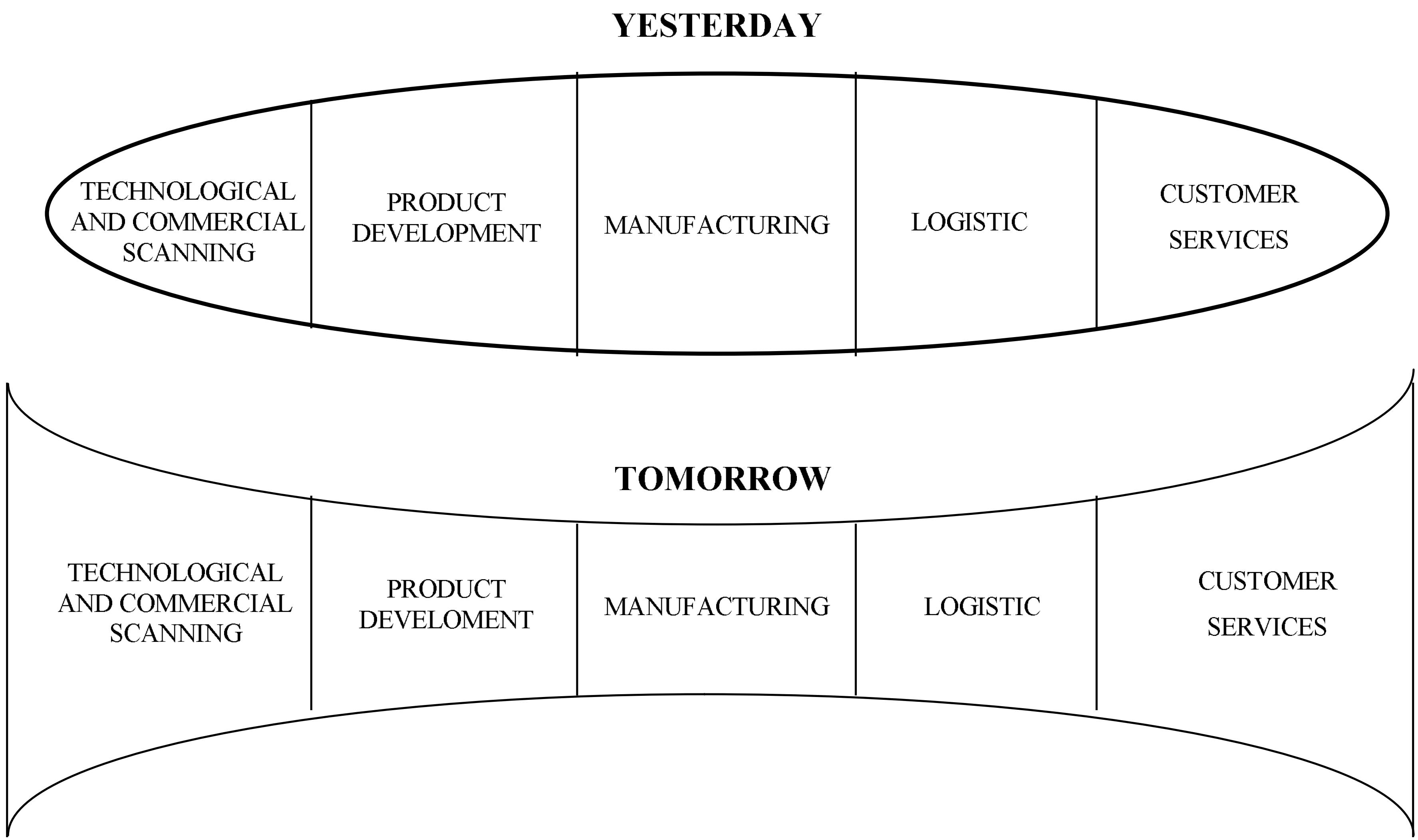


Figure 2
Evolution of core competencies



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