Small Modular Reactors: Licensing constraints and the way forward

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Licensing small modular reactors

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Abstract

SMR (Small Modular Reactor) is an acronym for a group of nuclear power plant designs receiving an increasing deal of attention from the industry and policy makers. A large number of SMRs need to be built in the same site and across the word to compensate diseconomies of scale and be cost competitive with large reactors and other base-load technologies. A major barrier is the licensing process, historically developed for large reactors, preventing the simply deployment of several identical units in different countries. This paper, discussing Ramana, Hopkins and Glaser [1], enlarges the view to all the SMR-related implications on the licensing process, presenting their legislative implications and market effects.

Keywords

SMR;

Licensing process;

Regulation;

Construction;

Modularity;

Economics

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1. Introduction

Ramana, Hopkins and Glaser in Ref. [1] provide an extensive review of the LP (Licensing Process) of SMR (Small Modular Reactors) in five countries: USA, Russia, South Korea, China and India. The leading reactor vendors for SMRs belong to those countries and the respective governments are keen to support this industry because of the vast potential for establishing a competitive advantage and thereby significant market share afforded to the first movers. The LPs of these countries are particularly important because, in order to gain credibility and demonstrate the technology, the reactor vendors aims firstly to build SMRs in their own country and then to export the technology to other countries. Consequently, governments (and their regulatory bodies) are considering the revision of existing LPs in order to tailor them for the assessment of SMRs.

The attractiveness of SMRs, as investment, is mostly based on the principle of modular deployment fostering both economies of multiples and investment scalability [2], [3] and [4]. Economies of multiples exist because of industrial learning, co-siting cost sharing and mini-mass production of components from suppliers. Scalability refers to the ability to echelon the investment and to decide if, and when, to increase the power (i.e. then the number of SMRs) installed in a certain site or utility portfolio [5]. The current research [1] primarily focuses on the issue of the EPZ (Emergency Planning Zone) because of the interest of coupling SMRs with other industrial plants; e.g. Ref. [6]. As such, it is important to locate SMRs close to industrial plants, hence the interest in EPZ. Although the EPZ is a key aspect of the LP it is important to be aware of other factors, as analyzed in this discussion paper. These aspects are crucial for the economics of SMRs.

2. Discussion

Five main additional topics should be considered while overviewing the challenge of licensing SMR:

1.

Typology of licensing approach

2.

Duration and predictability of the LP

3.

Regulatory harmonization and international certification

4.

Manufacturing License

5.

Ad Hoc legal and regulatory framework.

2.1. Typology of licensing approach

The IAEA distinguishes between two major typologies of licensing approach: prescriptive based and goal setting (or performance based) [7].

Prescriptive based approach (which is the most common: for instance, all countries mentioned into the paper adopt the prescriptive based licensing approach) is mostly based on the deterministic safety assessment [8] and [9]. The reactor design, material, components and the final facility are judged in their ability to respect pre-defined norms and principles. Under this approach, the regulator needs to develop (or to adopt) a wide range of codes and standards enabling this technical judgment [10]. Traditionally, the prescriptive based approach has worked properly, when few standardized reactors designs were deployed several times (e.g. France, South Korea, and Russia). From the licensing point of view, this approach is efficient because the codes and the standards are almost tailored to the specific reactor design and the country of construction. The main advantages of the "prescriptive based" LP (once it has been established) are the speed and efficiency especially for experienced industrial operators: reactor vendors, contractors, and operators. Furthermore, the approach aims to reduce the level of uncertainty and ambiguity of the LP and it aims to reduce the subjectivity left to the regulatory body [7] and [9]. For SMRs, the key challenge is the development of new "tailored" standards and codes enabling the issuance of prescriptive based LP. This is a challenge because the buyer-countries (but also vendors) may relay on different SMR-designs at the same time (because of technological, political, economic or strategic reasons); under such scenario, the regulatory burden could be a major challenge and a constrain. In particular [11] lists 30 designs under development, mostly in few nations (USA, Russia and Japan alone accounts for 21 designs).

The "goal setting approach" (or performance-based) is typical of nuclear countries that base the nuclear program an open market principle (rather than a country development strategy promoting the domestic industry); United Kingdom is an example [12] and [13]. Despite the USA Licensing systems is sometimes considered a prescriptive based approach, it also contains several elements of the goal setting one (this is in line with the open market proposition associated to USA nuclear program) [14]. Goal setting approach relays more extensively to the risk informed regulation [15], [16] and [17] in combination with the ALARA/ALARP (As Low As Reasonably Achievable/As Low As Reasonably Possible) principle [18], [19] and [20]. The approach is more flexible in considering a new reactor design technology; the downside is that the LP is perceived more ambiguous and uncertain by the applicant. Furthermore, the regulatory body have higher degree of subjectivity. This licensing approach relies extensively on the "design certification" together with the "site certification" (or Construction + Operation license) [21]. Design certification considers the general safety characteristic of a reactor design and would permit to certify the SMR specific design. The remaining licenses (that may change depending on the country considered) are site and project specific. Since prescriptive norms are not in place (e.g. limit to the radioactive discharges into the environment or other relevant constrains) these boundary conditions are fixed though the "license conditions" [22] and [23]. License conditions can be understood as a flexible regulatory mean that apply to the specific NPP (Nuclear Power Plant) rather than be general and uniform across the nuclear programme [24]. Usually, the regulatory body considers the effort and the time associated to the issuance of license conditions on case-by-case basis. By contrast, prescriptive based LP is more rigid and any relevant modification of the facility requires a new LP (this is a major constrain for modular facility). In the first phase, SMR could take advantage of the wider flexibility offered by goal setting approach, especially during the early phases of a nuclear program, while more technologies are assessed.

Summary: The types of licensing approach is a fundamental determinant for the deployment of SMRs. At this stage of development, the "goal setting approach" seems the most favorable to the deployment for SMR. Conversely, most of the countries involved (as reactor vendor, buyer or both) into a SMR nuclear program adopt a prescriptive based licensing approach.

2.2. Duration and predictability of the LP

Some of the key advantages of modular SMRs are: the scalability of the investment (deploying SMR when the demand of electricity rises), the reduced construction time and risk (SMRs are mostly manufactured in factories reducing the number of activities in the site) [25] and [26]. These SMRs' characteristics are essential for being economically and strategically competitive.

The existing LPs have been designed for large nuclear power plants characterized by a long construction period. Large plants require various assessments that take time and are performed in parallel with their construction. SMRs are designed for a shorter construction, consequently the “parallel” LP time could be longer than the SMR construction schedule time preventing the expected time saving. These constrains are due to two macro groups of reasons.

Firstly, the existing LPs may require additional time in order to cope with SMRs because of their peculiarities:

- Novelty of the design technology
- Issuance of different safety principles with respect the conventional nuclear power plants
- Lack of experienced and specific regulatory framework

Secondly, administrative and institutional activities affect the duration of the LP. In most of the nuclearized countries, the regulatory body is the independent administrative institution entitled to perform the technical safety assessment. However, several other institutions are involved into the LP; Table 1 shows some examples [12] and [27]. The multitude of institutions involved, and the various bureaucratic passages between them, imply a long licensing time. For example, only the public hearing and enquiries use to take about one year in most of the nuclearized countries.

Table 1.

Major institutions involved into the LP of nuclearized countries.

Country

Other major institutions rather than the regulatory body involved into the LP

Parliament

Government or ministers

Public hearing/Inquiry

Canada

√

√

Finland

√

√

√

France

√

√

India

√

√

Japan

√

√

Russia

√

√

South Korea

√

√

Unite Kingdom

√

USA

√

Summary: Existing LPs could extend the construction time of SMRs beyond the pure technical schedule undermining the overall economics.

2.3. Regulatory harmonization and international certification

One of the key debate concerning licensing SMR is about the regulatory harmonization [28] and [29]. In the nuclear industry, there are few major reactor vendors, contractors and "nuclear manufacturer suppliers". However, the nuclear industry operates internationally (several countries are interested in SMRs) while the LPs and the nuclear regulations are country-specific [28]. Consequently, a certain reactor vendor cannot "produce a standard plant" and simply ship/build identical units all over the world. A necessary precondition for the deployment of identical units in more than one country is the harmonization of law and LP.

Nowadays, the international harmonization is promoted by three key groups of stakeholders: the international organizations (e.g. the IAEA), the nuclear industry and the regulatory bodies. They have different perspectives and powers.

- The International organizations have, by definition, an international perspective and exercises power in an indirect manner [30] and [31].

- The nuclear industry is promoting the idea of harmonizing the nuclear regulation and LP in order to reduce the uncertainty and the knowledge burden required to develop a NPP [32] and [33]. This would be extremely beneficial to the feasibility of SMRs. They can lobby for this toward the government and regulatory bodies [34].

- Regulatory bodies are keen to collaborate at international level; with this respect, some mechanisms and devoted institutions are already in place (e.g. WENRA) [35]. Regulatory bodies can take advantage in sharing information, experience and knowledge about reactor designs that have been already certified in some countries and are applied to others. They have regulatory power in their own country [36].

Despite most of nuclear stakeholders would beneficiate for regulatory harmonization it is difficult to make significant progress in this direction in the short-medium term because of the heterogeneity of [14], [36] and [37]:

- Legal systems and jurisprudence

- Institutional systems

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LP structure and underlying principles

Legal and regulatory harmonization requires major amendments of the previous (at national level); this is hardly feasible in the short term.

Along with the regulatory harmonization, there is a debate over the international certification of the reactor designs. Under this envisaged approach, SMR designs could be certified once at international level and the remaining assessments (required for a complete LP) would be issued at local (country) level [33]. This approach would be extremely advantageous for the SMR industry. Again, even if this is attractive, it would be extremely challenging at legal and institutional level. It is difficult to redesign the existing legal norms and to reassign the institutional duties. International certifications would conflict with the country sovereignty. The implementation of this licensing option would require coordinated reforms at mandatory (law) level (in several countries together), the implementation of major international conventions and a massive administrative reorganization.

Summary: The fragmentation at country level of legal systems and jurisprudence, Institutional systems, LP structure constrain the SMRs standardization. Since each country has power on only itself the short term harmonization is unlikely.

2.4. Manufacturing license

The manufacturing license was introduced by the US Nuclear Regulatory Commission for certifying the processes of the critical nuclear suppliers (e.g. Nuclear Steam Supply System) [38]. The manufacturing license does not substitute the LP but it speeds up the LP because the manufactures are known and certified by the regulatory body. The deployment of SMRs would be favored by the manufacturing license. Manufacturing activities are extremely important for the SMRs: one of the key ideas of modularization is to move the work from the site to the factory. This means that most of the licensing activities would be potentially performed within one or more factories [39]. Therefore, the main challenges for the regulatory body would be: traceability of components by considering the whole supply chain, distributed LP (as opposed to the existing concentrated one: at the country and site where NPP is developed), etc. The aircraft industry is often suggested as reference [34]. In this industry, few manufacturers design and built the aircrafts. This environment would be comparable to the case of where the manufacturing license is completely substitutive to the LP. In such extreme circumstance, the LP would focus only (or mostly) on the manufacturing process rather than to its outcome (the SMR). This approach would be extremely beneficial for the SMR industry because it would permit an efficient manufacturing production.

Nowadays, the idea of “reactor certified in the factory” and then shipped and operated in the field is not feasible. The CNS I (first Convention of Nuclear Safety) [40] is the fundamental milestone for LP in nuclearized countries, and has been instituted in response to the accident of Chernobyl [14]. One of the key idea of the CNS I is the institution of the licensing principles [41] in order to assess the plant and the responsible organization (the nuclear operator). The key implication is that the reactor owner cannot get rid of the nuclear operator exclusive liability, as he is the ultimate and sole responsible for the nuclear safety. The plant must still be certified on site at the end of the construction.

Summary: Even if all the “mechanical components” are certified in the factory, the LP applies to another unit of analysis: the system installed on site. The nuclear operator is in all the cases the ultimate and sole responsible for the nuclear safety.

2.5. Ad Hoc legal and regulatory framework

Another line of thought is the development of specific laws, regulations and LP for SMRs. This approach is already common for small nuclear research facilities (e.g. they don't need public hearings and inquiries). The legislation identifies the exemption of circumstances by limiting both: the nominal thermal power (i.e. usually 50 MW) and the purpose of the facility (i.e. research activities) [7] and [42].

Three main challenges inhibit the adoption of a complete “Ad Hoc legal and regulatory framework”:

- It requires a significant review of the legal and regulatory framework
- It implies a complete re-think of the LP that implies a redefinition the institutional framework
- It implies a reduction of the licensing guarantees in intuitional and democratic terms (e.g. exemption of circumstances for the public inquiry). This reduction of guarantees is difficult to be justified in the eyes of the country citizens.

Summary: An ad hoc legislation process similar to the one for research reactors could be the way forward. However, there could be constrains in terms of public acceptability, and total power installed in the site. Research reactors are designed for being stand alone, not duplicated in the site and produce (usually) limited power.

3. Conclusions

SMRs are receiving increasing attention from both industry, academia and government. Unfortunately, there are several misconceptions regarding the LP of SMRs which have the effect of preventing a fair analysis of these power plants. In fact, a key advantage for the widespread adoption of SMRs is a tailored LP shared between several nations. The five key aspects discussed in this paper, along with the EPZ (well described by the original paper), are the main challenges associated to this long-term objective.

Tailoring of the LP for SMRs as part of a strong political commitment by several countries and at the same time is essential. Since there is not a single international authority with “full infinite power” and the regulatory bodies have limited ability to reshape the licensing framework (operating only at regulatory level) the national states play a pivotal role in the process. Their political commitment would require a set of legal reforms, deeply modifying the architecture and principles governing their LPs. This is unlikely to happen in the short-term and represents one of the main obstacles preventing the widespread adoption of SMRs.

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