

# DESIGN AND FUNCTIONALITY TESTING OF KARTINI RESEARCH REACTOR EDUCATIONAL SIMULATOR WEBSITE (SIRAKA)

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## ABSTRACT

**DESIGN AND FUNCTIONALITY TESTING OF KARTINI RESEARCH REACTOR EDUCATIONAL SIMULATOR WEBSITE (SIRAKA).** *Physical access to the Kartini Reactor as a research and educational facility is severely limited due to safety and regulatory factors. This study aims to design and develop an educational website simulator for the Kartini Reactor (SIRAKA) and to test its functionality and performance. The simulator was developed using a component-based architecture with React.js on the client side (client-side rendering) and implements point kinetics equation (PKE) computation with six delayed neutron groups on the Regulating Rod. Functionality testing was conducted using Blackbox Testing on 25 scenarios, while web performance testing used Google Lighthouse. Validation of PKE calculations was performed by comparing reactivity curves against rod position and observed reactor period. The results showed that all 25 Blackbox scenarios succeeded (100%), with Lighthouse scores of 92 (Performance), 96 (Accessibility), 100 (Best Practices), and 100 (SEO). Physics validation showed that the reactivity curve follows an S-shaped integral worth pattern with a critical point at 52–53% position and a total Regulating Rod worth of 0.0090  $\Delta k/k$ . Dynamic power simulation resulted in an observed reactor period of 0.98 seconds at 0.005157 reactivity, demonstrating behavior consistent with point kinetics theory. SIRAKA is declared feasible for use as an interactive web-based learning medium for the Kartini Reactor.*

**Keywords:** Reactor Simulator, Kartini Reactor, PKE, React.js, Blackbox Testing, Google Lighthouse.

## INTRODUCTION

Nuclear technology makes a significant contribution to various fields, including energy, healthcare, industry, and scientific research. In the field of healthcare, this technology is used for the diagnosis and treatment of diseases through nuclear medicine techniques [1]. In the industrial sector, nuclear technology is used for non-destructive testing and material quality control [2]. Meanwhile, in the field of research, nuclear reactors serve as a means of producing isotopes and advancing scientific knowledge [3].

Indonesia has three nuclear research reactors, one of which is the Kartini Reactor, located on the campus of the Indonesian Nuclear Technology Polytechnic in Yogyakarta. This reactor is a TRIGA Mark II pool-type reactor with a maximum power of 250 kW, but it is operated at 100 kW to support research, education, and training activities [4]. This reactor plays a strategic role as a learning resource for students and for the advancement of research on a national scale. However, access to nuclear reactor facilities is very limited due to safety concerns and strict regulations. [5], [6]. This lack of physical access is a major obstacle to efforts to improve nuclear technology literacy among high school and college students, especially for institutions that do not have direct access to reactor facilities [7].

Advances in information technology have opened up opportunities to overcome these limitations through the development of web-based reactor simulators. Web-based simulators offer advantages in terms of accessibility, collaboration, and learning integration compared to desktop applications [8]. In the context of nuclear engineering education, interactive simulators allow students to practice complex operations, visualize reactor behavior, and experience abnormal scenarios that are difficult to teach in a physical laboratory [9]. Various research reactor

simulators have been developed, including those for TRIGA reactors using LabVIEW [10], [11] and a code-based simulator for the Kartini Reactor [12].

However, the adoption of interactive web-based simulators with a Single Page Application (SPA) architecture in the nuclear ecosystem remains relatively slow. This study aims to design and develop the Kartini Reactor (SIRAKA) educational simulator website and to test its functionality and performance. The scope of the system is limited to web interface development, PKE computations applied only to the regulating rod, and testing of functionality (black-box testing) and web performance (Google Lighthouse). This research is expected to serve as an effective educational tool to enhance nuclear technology literacy through a safe and flexible digital approach.

## METODOLOGY

### System Architecture

SIRAKA was developed using a component-based architecture with the React.js framework on the client side. The Client-Side Rendering (CSR) approach was chosen so that the reactor physics simulation logic is executed entirely in the user's browser, eliminating communication latency with the server (zero-latency response) [13]. This architecture enables dynamic and responsive updates to the user interface in response to user interactions [14]. The system flowchart is shown in Figure 1.

**Flowchart SIRAKA**

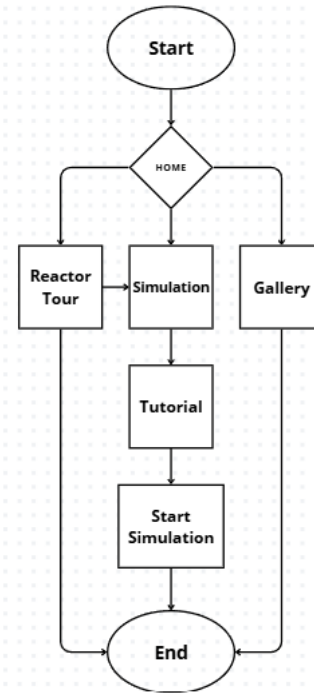


Figure 1. SIRAKA System Architecture Flowchart

### Implementation of the PKE Model

The simulation model was developed based on the Point Kinetics Equation (PKE) with six delayed neutron groups to describe changes in reactor power resulting from changes in reactivity [15], [16]. The differential equations used are as follows:

$$\frac{dn(t)}{dt} = \frac{\rho(t) - \beta}{\Lambda} n(t) + \sum_{i=1}^6 \lambda_i C_i(t) + S \quad (1)$$

$$\frac{dC_i(t)}{dt} = \frac{\beta_i}{\Lambda} n(t) - \lambda_i C_i(t) \quad (2)$$

di mana:

$n(t)$  = neutron population (relative power)

$\rho(t)$  = reactivity ( $\Delta k/k$ )

$\beta$  = total delayed neutron fraction (0,006502 for U-235)

$\beta_i$  = delayed neutron fraction of the nth group  $i$

$\Lambda$  = neutron generation time ( $1 \times 10^{-5}$  second)

$\lambda_i$  = decay constant of the precursor of the -th group  $i$

$C_i(t)$  = concentration of the nth group of delayed neutron precursors  $i$

$S$  = startup neutron source ( $1 \times 10^{-5}$ )

The physical constants used refer to the characteristics of the UZrH-fueled Kartini Reactor [4]. The values of  $\beta_i$  and  $\lambda_i$  for the six groups of uranium-235 delayed neutrons are presented in Table 1.

Table 1. Delayed Neutron Parameters for Six Groups (U-235)

Group ( $i$ )	Fraction ( $\beta_i$ )	Decay Constant ( $\lambda_i$ ) [ $s^{-1}$ ]
1	0,000215	0,0124
2	0,001424	0,0305
3	0,001274	0,1115
4	0,002568	0,301
5	0,000748	1,138
6	0,000273	3,01

The reactivity function for the regulating rod is calculated using the S-curve integral approach (integral worth curve) with a sixth-order polynomial:

$$H(x) = \frac{129,16}{6}x^6 + \frac{279,95}{5}x^5 - \frac{215,04}{4}x^4 + \frac{58,294}{3}x^3 + \frac{1,3702}{2}x^2 - 0,0029x$$

Where  $x$  = normalized control rod position (0–1). The total worth of the regulating rod is set to 0.0090  $\Delta k/k$  according to the TRIGA Mark II reactor characteristics [10].

The differential equation is solved numerically using the fourth-order Runge-Kutta (RK4) method with 500 substeps per iteration to ensure computational stability and accuracy [17]. The code is implemented in React.js using a custom hook, `useReactorPhysics`, which manages the neutron population and precursor concentration states. Key code snippets for the reactivity function and simulation step are presented in Listing 1.

```
// Reactivity calculation function for the Regulating Rod
function calculateRho(safe_pct, shim_pct, reg_pct) {
  if (safe_pct <= 0.05) return -0.0250; // SCRAM
  if (shim_pct < 0.50) return -0.0100; // Subkritis

  let rho_base = RHO_EXCESS_CORE - WORTH_REG; // -0.0030
  if (shim_pct >= 0.50) rho_base += 0.0004;

  const xn_reg = 1 - reg_pct;
  const absorb_reg = WORTH_REG * (integrateH0(xn_reg) / H_TOTAL);
  const rho_reg = WORTH_REG - absorb_reg;

  return rho_base + rho_reg;
}

// Simulation step using RK4
const stepSimulation = (rods, dt_real = 0.05) => {
  const rho = calculateRho(
    rods.safe / 100,
    rods.shim / 100,
    rods.regulate / 100
  );
  // ... RK4 iteration with 500 sub-steps
};
```

Listing 1. Code Snippet for PKE Implementation in React.js

In this study, the new PKE implementation was applied to the regulating rod. The safety rod functions as a SCRAM trigger (when its position is  $\leq 5\%$ ), while the shim rod functions as a subcritical lock (when its position is  $< 50\%$ ) without a complete calculation of the kinetics of the critical point.

#### Test Scenario

##### 1. Black-Box Testing Scenarios

Interface functionality testing was conducted using 25 scenarios covering page navigation, control bar interactions, 3D visualization, and operational parameter graphs. Each scenario was tested with specific inputs, and the expected results were predetermined.

##### 2. Google Lighthouse Scenario

Web performance testing was conducted using Google Lighthouse version 13.4.0 with desktop emulation. The metrics measured included First Contentful Paint (FCP), Largest Contentful Paint (LCP), Total Blocking Time (TBT), Cumulative Layout Shift (CLS), and Speed Index. The audit also covered accessibility, best practices, and SEO.

### 3. Physical Validation Scenarios

The validation of PKE calculations is conducted in two stages:

- a. Static validation was performed by calculating the reactivity for each regulating rod position from 0–100% in 5% increments, with the safe rod set at 100% and the shim rod at 50%. The results were compared with the theoretical integral worth curve for the TRIGA reactor.
- b. Dynamic validation is performed by running a 10 second simulation with the regulating rod at 80% (reactivity 0.005157), then calculating the reactor period from the power-versus-time data. The reactor period ( $T$ ) is calculated from the slope of the  $\ln(P)$  versus  $t$  curve in the steady-state region.

## RESULTS AND DISCUSSION

### Interface Design Results

SIRAKA has been successfully developed as a dynamic website with three main pages: the Home Page (Landing Page), the History Page (Tour), and the Gallery Page. The main feature of SIRAKA is the Simulator Page, which displays 2D visualizations of the reactor terrace, control panels, and operating parameter graphs.

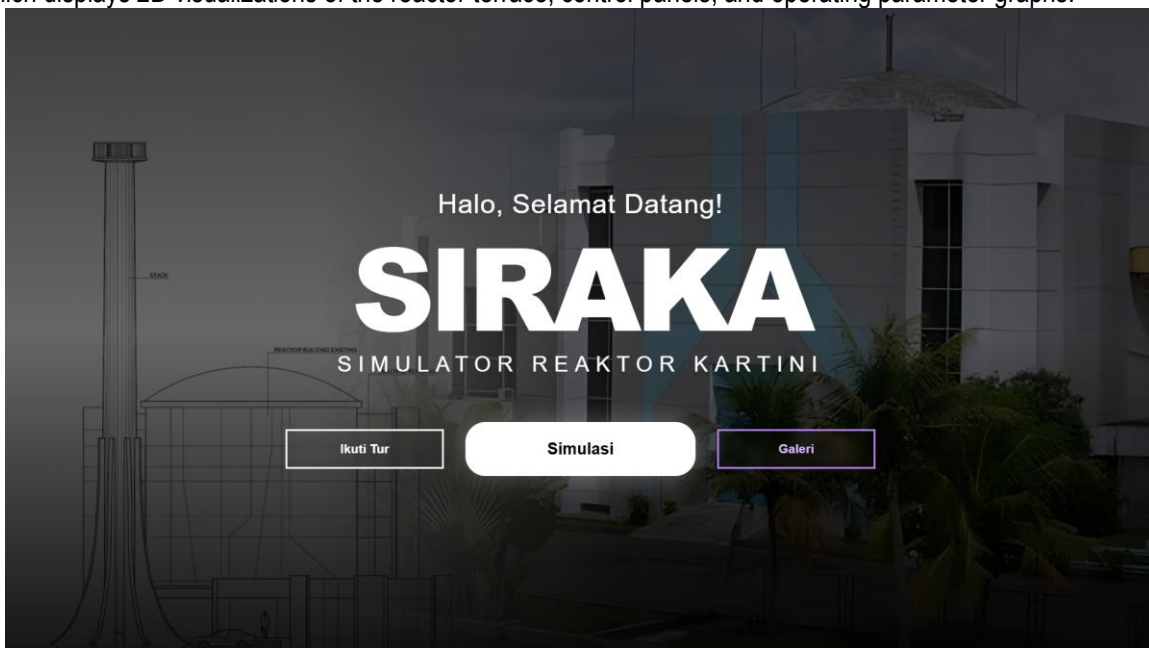


Figure 2. SIRAKA Home Page (Landing Page)

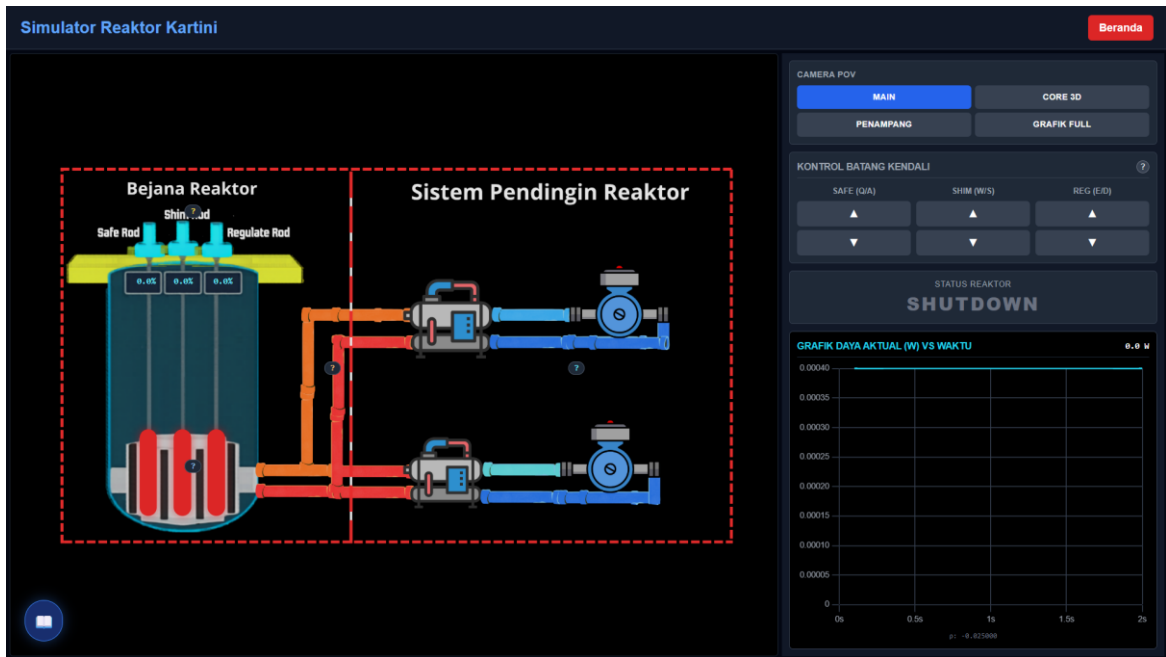


Figure 3. Reactor Simulator Page Interface

The Simulator page displays a 2D representation of the reactor core showing three control rods (Safe Rod, Shim Rod, Regulating Rod). Users can move the control rods using keyboard keys (Space + Q/W/E to move up, Space + A/S/D to move down). Any change in the position of the Regulating Rod affects the reactor's reactivity and power in real time. The control panel on the right provides navigation to the 3D Core, 3D Cross-Section, and Full Graph views.

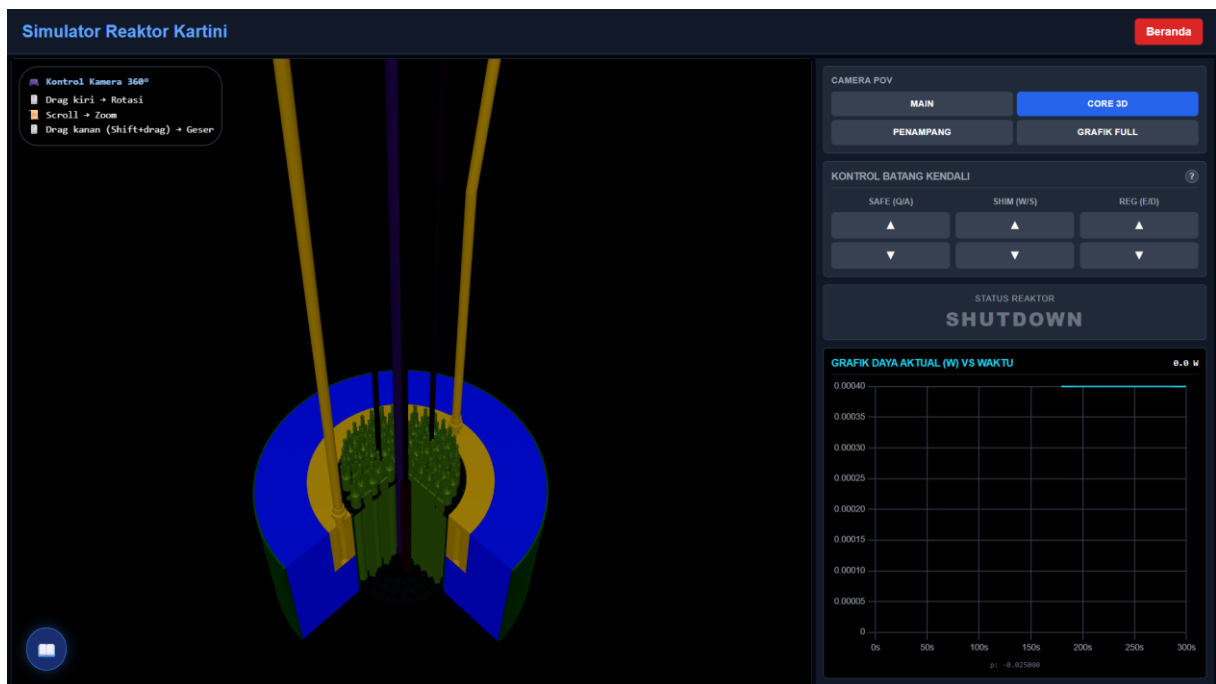


Figure 4. Core 3D Visualization of the Kartini Reactor

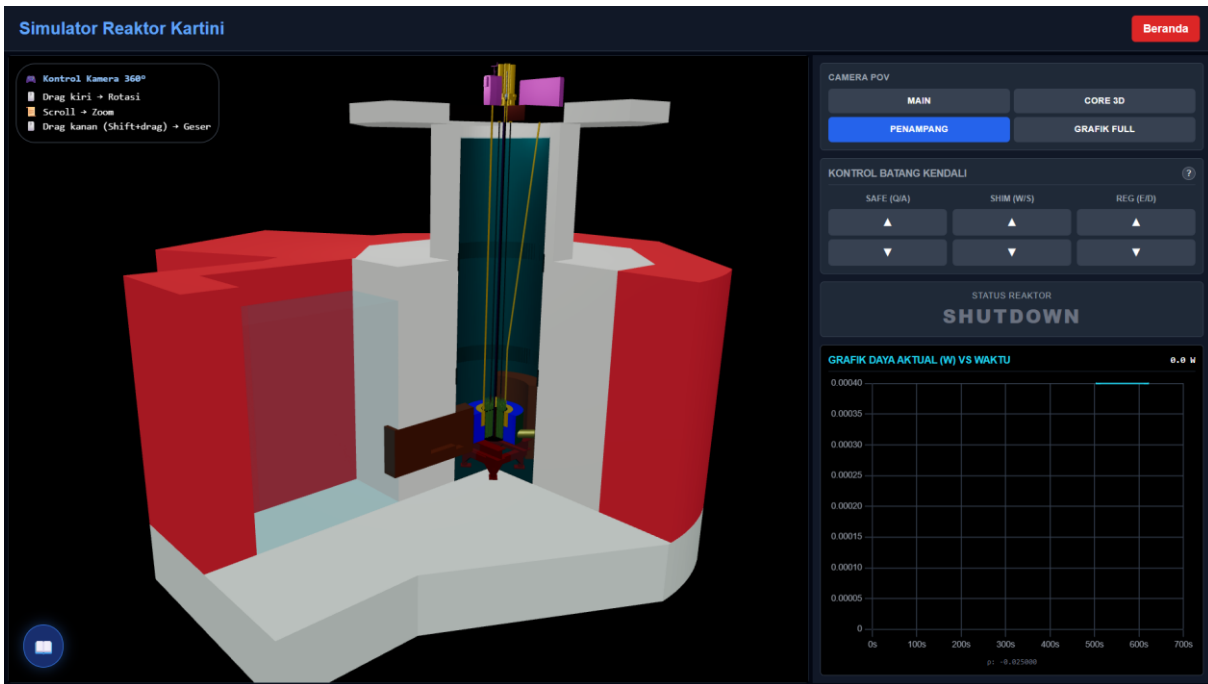


Figure 5. 3D Cross-Section Visualization of the Kartini Reactor

The Core 3D feature displays a three-dimensional model of the reactor core that can be rotated 360 degrees, zoomed in on, and panned. The 3D Cross-Section feature displays a cross-section of the entire reactor system, from the pool to the core. The Full Graph page presents three graphs: actual power versus time, reactivity profile, and delayed neutron precursor concentration.



Figure 6. Reactor Operating Parameters Graph (Full Graph)

#### Functionality Test Results (Black-Box Testing)

Black-box testing was conducted on 25 scenarios covering page navigation, control bar interactions, 3D visualization, and graphics features. The test results showed that all scenarios were successful, with a 100% success rate. The complete black-box test table is included in Appendix 1. All 25 scenarios were marked as successful, indicating that SIRAKA has met the functional requirements as a web-based simulation and learning platform for the Kartini Reactor.

## Web Performance Test Results (Google Lighthouse)

Web performance testing using Google Lighthouse version 13.4.0 with desktop emulation yielded the scores shown in Table 3.

Table 2. SIRAKA Google Lighthouse Score

Category	Score
Performance	92
Accessibility	96
Best Practices	100
SEO	100

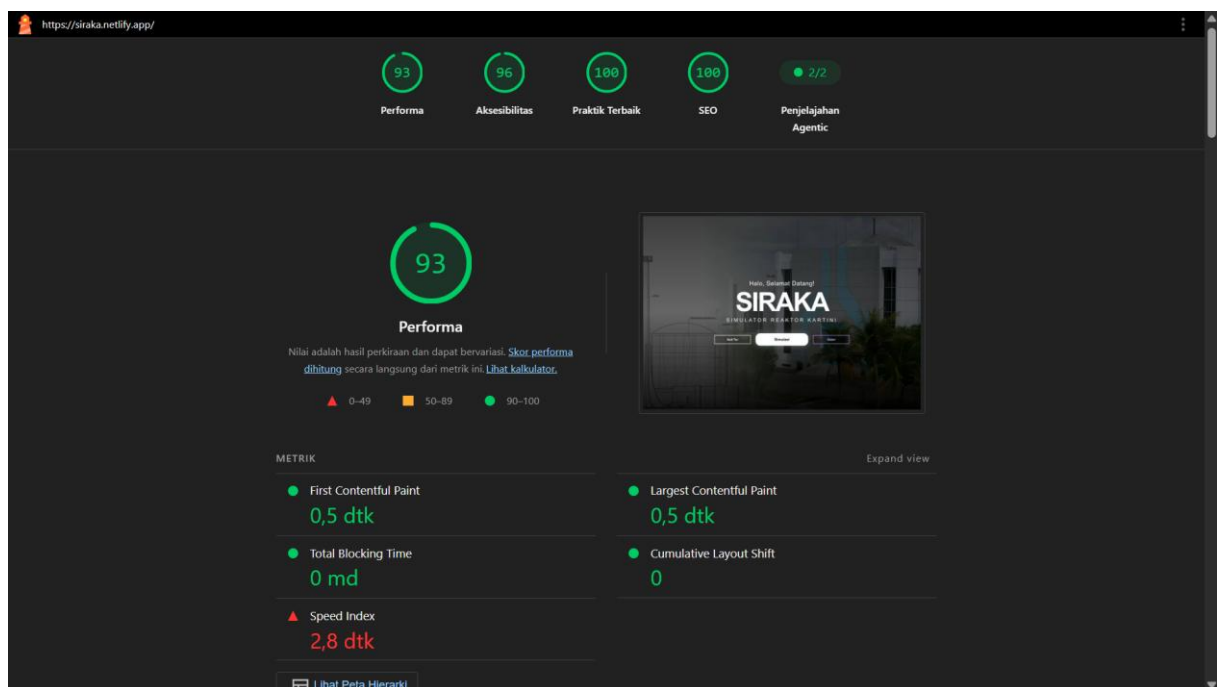


Figure 7. SIRAKA Google Lighthouse Audit Results

Performance metric details show the following results :

1. First Contentful Paint (FCP): 0.9 seconds (fast category)
2. Largest Contentful Paint (LCP): 0.9 seconds (fast category)
3. Total Blocking Time (TBT): 0 ms (excellent category)
4. Cumulative Layout Shift (CLS): 0 (excellent category)
5. Speed Index: 2.6 seconds (fast category)

A performance score of 92 indicates that SIRAKA has excellent loading performance. FCP and LCP metrics below 1 second indicate that the page's main content is displayed to users quickly. A TBT of 0 ms indicates that no JavaScript tasks are blocking the main thread, resulting in excellent page responsiveness. A CLS of 0 indicates that no elements shift during loading.

The Lighthouse audit also identified several opportunities for improvement:

1. A request to block rendering, with an estimated savings of 80 ms, caused by the initial CSS and JavaScript files.
2. Large image sizes, particularly Cover.png at 1,512 KB, which could be reduced by up to 1,174 KB if converted to WebP or AVIF format.

- Unused JavaScript totaling 283 KB out of a total of 374 KB that can be reduced.

From an analytical perspective, the presence of 3D objects (Core 3D and 3D Cross-Section) that use WebGL does not cause significant latency during initial loading, as the 3D models are loaded lazily when users access those features. This is evidenced by the FCP and LCP remaining below 1 second. However, the size of the background image on the landing page is the main contributor to the payload size (1,512 KB), which needs to be optimized in the future.

#### Validation of PKE Calculations

##### Static Validation (S-Curve)

The reactivity calculation results for each regulating rod position (0–100%) at 5% intervals are presented in Appendix 2 and visualized in Figure 8

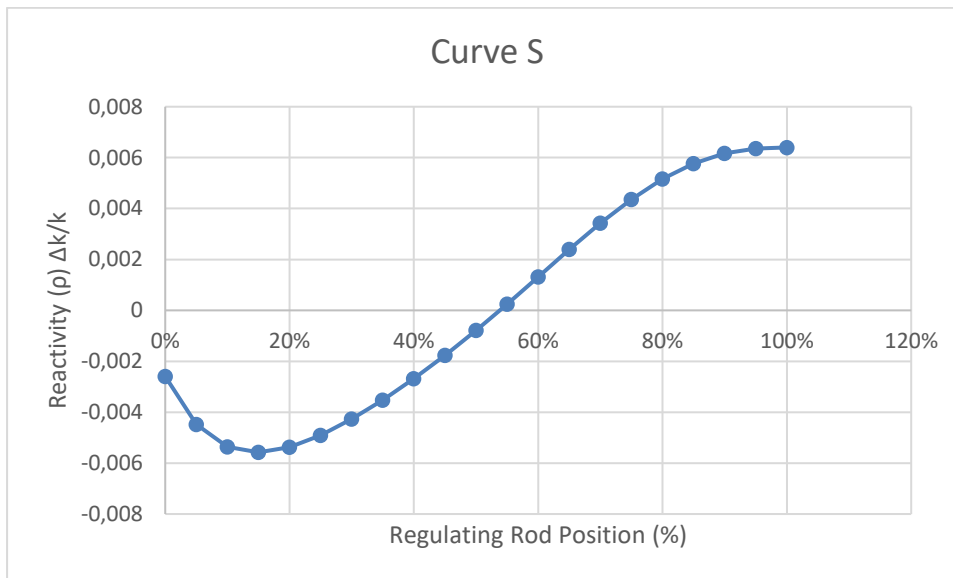


Figure 8. Static Reactivity vs. Regulating Rod Position Validation Curve (S Curve)

The reactivity curve versus control rod position exhibits an S-shaped pattern (S-curve), which is a characteristic of the TRIGA reactor control rods [10], [18]. At positions between 0–15%, reactivity initially decreases because the rod is in the low-efficiency region (the rod tip). At positions between 20–50%, reactivity rises gradually. At positions 50–80%, reactivity rises sharply as the rod passes through the region with the highest neutron flux gradient (the center of the core). At positions 80–100%, the increase levels off again.

The critical point ( $\rho = 0$ ) occurs at a position between 50–55%, specifically around 52–53%. This value is realistic for the TRIGA research reactor, where the control rods must be withdrawn about halfway to reach criticality [19]. The calculated total worth of the control rod is 0.0090  $\Delta k/k$  (ranging from -0.0026 at the 0% position to +0.0064 at the 100% position), which is identical to the WORTH\_REG design constant in the code. This proves that the implementation of the integral polynomial integrateH0 successfully calculates the total worth of the rod accurately.

##### Dynamic Validation (Power vs. Time)

The power dynamics simulation was performed under the following conditions: Safe Rod = 100%, Shim Rod = 50%, and Regulating Rod = 80% (reactivity = 0.005157). The results of the 10-second simulation are presented in Appendix 3 and visualized in Figure 9.

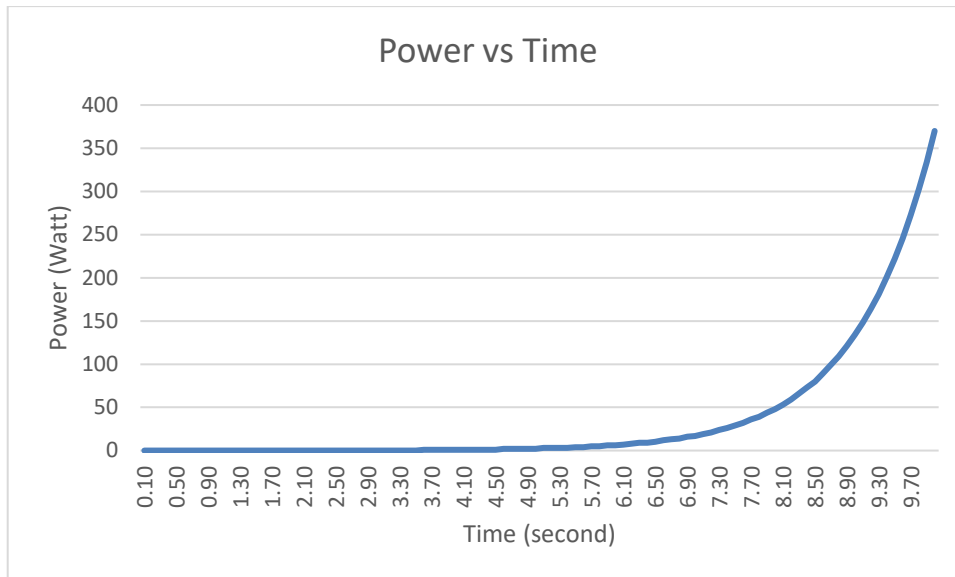


Figure 9. Dynamic Power vs. Time Validation Graph (10-second Simulation)

The power increase follows an exponential pattern consistent with the solution to the point-source kinetic equation for a constant positive reactivity. The initial power is very small (on the order of  $1 \times 10^{-7}$ ) due to the startup neutron source effect ( $SOURCE = 1 \times 10^{-5}$ ), which takes about 4 seconds for the population to become large enough to be measurable in watts. After that, the power rises exponentially from 2 W at the 5th second to 370 W at the 10th second.

The observed reactor period was calculated from the data for the last 2 seconds (seconds 8–10) using linear regression on the  $\ln(P)$  vs  $t$  curve. The calculation yielded a reactor period of 0.98 seconds. This value indicates that the power increases by a factor of  $e$  (2.718) every 0.98 seconds. A positive period of 0.98 seconds indicates that the reactor is still in a sub-prompt critical state ( $\rho < \beta$ ), since  $\rho = 0.005157 < \beta = 0.006502$ . This is consistent with point kinetics theory, which states that for  $\rho < \beta$ , the reactor period is positive and the reactor is still controlled by delayed neutrons [20].

A comparison with similar studies shows consistent results. The previously developed code-based Kartini simulator reported good agreement for power versus control rod position [12]. Another TRIGA simulator also used a six-group PKE with fuel temperature feedback and achieved an accuracy of within 5% compared to experimental data [10], [18]. Thus, the PKE model implemented in SIRAKA has been validated both qualitatively (S-curve shape) and quantitatively (reactor period and critical point).

## CONCLUSION

Based on the results of research conducted on the design and functional testing of the Kartini Reactor (SIRAKA) educational simulator website, it can be concluded that the system has been successfully developed as a web-based interactive learning tool with a client-side rendering architecture using the React.js framework. This system provides comprehensive simulation features, including a two-dimensional visualization of the reactor core, three-dimensional models (3D Core and 3D Cross-Section), and operational parameter graphs displaying actual power, reactivity profiles, and delayed neutron precursor concentrations in real time. In terms of functionality, Blackbox Testing on 25 scenarios showed a 100% success rate, proving that all navigation features, control rod interactions, visualizations, and graph updates function according to the designed specifications. Web performance testing using Google Lighthouse yielded excellent scores: 92 for performance, 96 for accessibility, 100 for best practices, and 100 for SEO, with First Contentful Paint and Largest Contentful Paint metrics under one second, Total Blocking Time of zero milliseconds, and Cumulative Layout Shift of zero, indicating that the presence of 3D objects does not cause significant latency during initial page loading. Validation of the physics calculations for the Regulating Rod control rod proves that the implemented six-group delayed neutron Point Kinetic Equation (PKE) model is not arbitrary, as demonstrated by a reactivity curve following an S-shaped integral worth pattern with a critical point at 52–53% and a total rod worth of  $0.0090 \Delta k/k$ , as well as power dynamics simulations yielding an observed reactor period of 0.98 seconds under supercritical conditions, which is consistent with point kinetics

theory. Overall, SIRAKA is deemed suitable for use as an educational tool to enhance public understanding—particularly in the field of education—regarding the operating principles and behavior of the Kartini Reactor through an information technology-based simulation approach.

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## REFERENCES

- [1] S. Luo, “Application of Nuclear Technology in Medicine,” 2023, pp. 263–308. doi: 10.1007/978-981-99-3087-6.
- [2] M. H. Al-Saleh and U. Sundararaj, “X-band EMI shielding mechanisms and shielding effectiveness of high structure carbon black/polypropylene composites,” *J. Phys. D. Appl. Phys.*, vol. 46, no. 3, p. 35304, 2013, doi: 10.1088/0022-3727/46/3/035304.
- [3] A. van de Wiel and M. Blaauw, “Medical Applications of a Nuclear Reactor,” *Am. J. Intern. Med.*, vol. 7, no. 1, p. 1, 2019, doi: 10.11648/J.AJIM.20190701.11.
- [4] BATAN, “Buku Putih Pemanfaatan Reaktor Riset di Indonesia,” 2019.
- [5] E. Edwards, A. Sweet, M. Blanchard, R. Agasie, and P. Jain, “Distance reactor laboratory and virtual tours,” *Trans. Am. Nucl. Soc.*, vol. 94, pp. 33–35, 2006.
- [6] Z. Hoyda, K. Atkinson, and A. Situm, “A Review of the Capabilities and Gaps in Canada’s Research Reactors for Facilitating the Development and Deployment of Small Modular Reactors,” *Nucl. Technol.*, vol. 211, pp. 1347–1362, 2024, doi: 10.1080/00295450.2024.2409589.
- [7] O. Novák, T. Bílý, O. Huml, L. Sklenka, F. Fejt, and J. Rataj, “Online training and education from the VR-1 reactor—Lessons learned,” *Nucl. Eng. Technol.*, 2023, doi: 10.1016/j.net.2023.08.020.
- [8] W. F. Polik and J. R. Schmidt, “WebMO: Web-based computational chemistry calculations in education and research,” *Wiley Interdiscip. Rev. Comput. Mol. Sci.*, vol. 12, 2021, doi: 10.1002/wcms.1554.
- [9] A. K. Alkaabi, M. Ali, H. J. Yoon, and O. Ashy, “Simulator assisted engineering - applications in nuclear engineering education at Khalifa University,” *EPJ Web Conf.*, vol. 247, p. 14003, 2021, doi: 10.1051/epjconf/202124714003.
- [10] J. Malec, D. Tožkan, and L. Snoj, “PC-based JSI research reactor simulator,” *Ann. Nucl. Energy*, vol. 146, p. 107630, 2020, doi: 10.1016/j.anucene.2020.107630.
- [11] A. Z. Mesquita, A. A. M. Felipe, A. M. F. Lage, and P. A. M. Ribeiro, “Visual interfaces for the digital simulation system of the IPR-R1 Triga nuclear research reactor,” *ACCENTS Trans. Image Process. Comput. Vis.*, vol. 6, no. 21, pp. 80–90, 2020, doi: 10.19101/TIPCV.2020.618054.
- [12] Sutanto, I. Nafisah, A. R. Antariksawan, and J. Wu, “Improvement of a code-based Kartini reactor simulator for education and training,” *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 13, no. 4, 2023, doi: 10.18517/ijaseit.13.4.18282.

- [13] T. F. Iskandar, M. Lubis, T. F. Kusumasari, and A. R. Lubis, "Comparison between client-side and server-side rendering in the web development," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 801, p. 12136, 2020, doi: 10.1088/1757-899X/801/1/012136.
- [14] M. A. Romanov, A. O. Badalin, D. V Ribalka, and A. E. Bazhenov, "Analysis and comparative study of architectural approaches to the development of single-page applications (SPA, SSR, SSG)," *Program. Sist. Vychisl. Metody*, no. 4, pp. 108–117, 2025, doi: 10.7256/2454-0714.2025.4.77190.
- [15] M. S. El-Genk and J.-M. Tournier, "A point kinetics model for dynamic simulations of next generation nuclear reactor," *Prog. Nucl. Energy*, vol. 92, pp. 91–103, 2016, doi: 10.1016/j.pnucene.2016.07.007.
- [16] K. Prantikos, L. Tsoukalas, and A. Heifetz, "Physics-informed neural network solution of point kinetics equations for a nuclear reactor digital twin," *Energies (Basel)*, vol. 15, no. 20, p. 7697, 2022, doi: 10.3390/en15207697.
- [17] D. Juszczuk, J. Tarnawski, T. Karla, and K. Duzinkiewicz, "Real-time basic principles nuclear reactor simulator based on client-server network architecture with web browser as user interface," Jun. 2017, pp. 344–353. doi: 10.1007/978-3-319-60699-6\_33.
- [18] C. Introini, A. Cammi, S. Lorenzi, and G. Magrotti, "An improved zero-dimensional model for simulation of TRIGA Mark II dynamic response," *Prog. Nucl. Energy*, 2018, doi: 10.1016/j.pnucene.2018.10.025.
- [19] J. Riede and H. Boeck, "Numerical simulation of non-steady state neutron kinetics of the TRIGA Mark II reactor Vienna," *Nucl. Eng. Des.*, vol. 265, pp. 872–879, 2013, doi: 10.1016/j.nucengdes.2013.06.030.
- [20] R. P. D. Carvalho and J. R. Maiorino, "A research reactor simulator for operators training and teaching," Jul. 2006.

## APPENDIX

Appendix 1. Black-Box Testing Table

No	Test Scenario	Input	Expected Result	Test Results	Status
1	Opening the website	Accessing the Siraka URL	The website's homepage displays correctly	The homepage was successfully displayed	Success
2	Opening the Tour menu	Click the "Take the Tour" button	The tour page opens and displays information about the Kartini Reactor	Tour information has been successfully displayed	Success
3	Return to the home page from the tour menu	Click the Back button	The home page is displayed again	The home page has been successfully displayed	Success
4	Open the Gallery menu	Click the Gallery button	The gallery page displays a collection of images and documentation	The gallery has been successfully displayed	Success
5	Navigate through the images using the "Next" button	Click the "Next" arrow icon on the gallery view	The page displays the next image in order	The next image was successfully displayed	Success
6	Navigate through images using the "Previous" button	Click the "previous" arrow icon in the gallery view	Page displaying the previous image	The previous image was successfully displayed	Success
7	Return to the home screen from the gallery menu	Click the Back button	The home page is displayed again	The main page was successfully displayed	Success
8	Open the Simulation menu	Click the Simulation button	The simulator page has loaded successfully	The simulator has been successfully displayed	Success
9	Return to the home page from the simulation menu	Click the back button	The home page is displayed again	The main page has been successfully displayed	Success
10	Displaying usage instructions	Click the Next button	The next instructions are displayed	The instructions were successfully displayed	Success

No	Test Scenario	Input	Expected Result	Test Results	Status
11	Skip instructions	Click the Skip button	Go directly to the simulator page	The simulator has been successfully displayed	Success
12	Raise the Safe Rod	Press Space + Q	Safe Rod percentage increases	The Safe Rod has been raised	Success
13	Lower the Safe Rod	Press Space + A	Safe Rod percentage decreases	Safe Rod successfully lowered	Success
14	Raise the Shim Rod	Press Space + W	The Shim Rod can be raised	The shim rod was successfully raised	Success
15	Lower the Shim Rod	Press Space + W	Shim Rod cannot be raised	The system rejected the command	Success
16	Displaying reactor power	Changing the control rod position	Reactor power changes according to conditions	Reactor power changes	Success
17	Displaying the reactor status	Running a simulation	Reactor status is displayed in real time	Status successfully displayed	Success
18	Displaying the 3D core menu	Click the Core 3D button	The Core 3D view is displayed	The Core 3D interface has been successfully displayed	Success
19	Rotating Core 3D Objects	Click and drag with the mouse	The 3D object rotates in the direction of the cursor's movement	The object has been successfully rotated as instructed	Success
20	Zoom on Core 3D Object	Scroll the mouse wheel up or down	The object's display size increases or decreases	The object view has been successfully zoomed in and out	Success
21	Move the Core 3D object	Press and hold the Shift key, then drag	The object moves in the direction of the drag	The object was successfully moved as instructed	Success
22	Display the cross-section menu	Click the cross-section button	The cross-section menu is displayed	The cross-section view has been successfully displayed	Success

No	Test Scenario	Input	Expected Result	Test Results	Status
23	Rotate Cross-Section Object	Click and drag with the mouse	The cross-section rotates in the direction of the cursor's movement	The cross-section has been successfully rotated as instructed	Success
24	Zoom in on the cross-section	Scroll the mouse wheel up or down	The cross-section view size increases or decreases	View The cross-section has been successfully zoomed in and out	Success
25	Move the Cross-Section Object	Press and hold the Shift key, then drag	The cross-section moves in the direction of the drag	The cross-section has been successfully moved as instructed	Success

Appendix 2. Relationship Between Regulating Rod Position and Reactivity

Regulating Rod Position (%)	Reactivity ( $\rho$ ) $\Delta k/k$	Status
0%	-0,0026	Subcritical
5%	-0,004481	Subcritical
10%	-0,005358	Subcritical
15%	-0,005576	Subcritical
20%	-0,005374	Subcritical
25%	-0,004906	Subcritical
30%	-0,004271	Subcritical
35%	-0,00352	Subcritical
40%	-0,002681	Subcritical
45%	-0,001766	Subcritical
50%	-0,000784	Subcritical
55%	0,000252	Near-Critical
60%	0,001321	Critical (Super)
65%	0,002392	Critical (Super)
70%	0,003421	Critical (Super)
75%	0,00436	Critical (Super)
80%	0,005157	Critical (Super)
85%	0,005768	Critical (Super)
90%	0,006167	Critical (Super)
95%	0,006359	Critical (Super)
100%	0,0064	Critical (Super)

Appendix 3. Simulation Results: Power vs. Time (Regulating Rod = 80%)

Time (second)	Power (Watt)	Relative Power (n)	Reactivity
0.10	0	1,09E-03	0.005157
0.20	0	1,28E-03	0.005157

Time (second)	Power (Watt)	Relative Power (n)	Reactivity
0.30	0	1,48E-03	0.005157
0.40	0	1,70E-03	0.005157
0.50	0	1,94E-03	0.005157
0.60	0	2,20E-03	0.005157
0.70	0	2,49E-03	0.005157
0.80	0	2,81E-03	0.005157
0.90	0	3,15E-03	0.005157
1.00	0	3,54E-03	0.005157
1.10	0	3,96E-03	0.005157
1.20	0	4,43E-03	0.005157
1.30	0	4,95E-03	0.005157
1.40	0	5,52E-03	0.005157
1.50	0	6,15E-03	0.005157
1.60	0	6,85E-03	0.005157
1.70	0	7,62E-03	0.005157
1.80	0	8,47E-03	0.005157
1.90	0	9,42E-03	0.005157
2.00	0	1,05E-02	0.005157
2.10	0	1,16E-02	0.005157
2.20	0	1,29E-02	0.005157
2.30	0	1,43E-02	0.005157
2.40	0	1,59E-02	0.005157
2.50	0	1,76E-02	0.005157
2.60	0	1,95E-02	0.005157
2.70	0	2,17E-02	0.005157
2.80	0	2,40E-02	0.005157
2.90	0	2,66E-02	0.005157
3.00	0	2,95E-02	0.005157
3.10	0	3,27E-02	0.005157
3.20	0	3,63E-02	0.005157
3.30	0	4,02E-02	0.005157
3.40	0	4,45E-02	0.005157
3.50	0	4,93E-02	0.005157
3.60	1	5,46E-02	0.005157
3.70	1	6,05E-02	0.005157
3.80	1	6,70E-02	0.005157
3.90	1	7,42E-02	0.005157
4.00	1	8,22E-02	0.005157
4.10	1	9,10E-02	0.005157
4.20	1	1,01E-01	0.005157
4.30	1	1,12E-01	0.005157
4.40	1	1,24E-01	0.005157
4.50	1	1,37E-01	0.005157

Time (second)	Power (Watt)	Relative Power (n)	Reactivity
4.60	2	1,52E-01	0.005157
4.70	2	1,68E-01	0.005157
4.80	2	1,86E-01	0.005157
4.90	2	2,06E-01	0.005157
5.00	2	2,28E-01	0.005157
5.10	3	2,52E-01	0.005157
5.20	3	2,79E-01	0.005157
5.30	3	3,09E-01	0.005157
5.40	3	3,43E-01	0.005157
5.50	4	3,79E-01	0.005157
5.60	4	4,20E-01	0.005157
5.70	5	4,65E-01	0.005157
5.80	5	5,15E-01	0.005157
5.90	6	5,70E-01	0.005157
6.00	6	6,31E-01	0.005157
6.10	7	6,99E-01	0.005157
6.20	8	7,74E-01	0.005157
6.30	9	8,56E-01	0.005157
6.40	9	9,48E-01	0.005157
6.50	10	1,05E+00	0.005157
6.60	12	1,16E+00	0.005157
6.70	13	1,29E+00	0.005157
6.80	14	1,42E+00	0.005157
6.90	16	1,58E+00	0.005157
7.00	17	1,75E+00	0.005157
7.10	19	1,93E+00	0.005157
7.20	21	2,14E+00	0.005157
7.30	24	2,37E+00	0.005157
7.40	26	2,62E+00	0.005157
7.50	29	2,90E+00	0.005157
7.60	32	3,22E+00	0.005157
7.70	36	3,56E+00	0.005157
7.80	39	3,94E+00	0.005157
7.90	44	4,36E+00	0.005157
8.00	48	4,83E+00	0.005157
8.10	53	5,35E+00	0.005157
8.20	59	5,92E+00	0.005157
8.30	66	6,56E+00	0.005157
8.40	73	7,26E+00	0.005157
8.50	80	8,04E+00	0.005157
8.60	89	8,90E+00	0.005157
8.70	99	9,85E+00	0.005157
8.80	109	1,09E+01	0.005157

<b>Time (second)</b>	<b>Power (Watt)</b>	<b>Relative Power (n)</b>	<b>Reactivity</b>
8.90	121	1,21E+01	0.005157
9.00	134	1,34E+01	0.005157
9.10	148	1,48E+01	0.005157
9.20	164	1,64E+01	0.005157
9.30	181	1,81E+01	0.005157
9.40	201	2,01E+01	0.005157
9.50	222	2,22E+01	0.005157
9.60	246	2,46E+01	0.005157
9.70	273	2,73E+01	0.005157
9.80	302	3,02E+01	0.005157
9.90	334	3,34E+01	0.005157
10.00	370	3,70E+01	0.005157