NUCLEAR POWER PLANT SIMULATOR FOR GENERAL PUBLIC

N. Škorić, A. Kavčič, B. Grobelnik

1Croatian Nuclear Society, Zagreb, Croatia
2Nuclear Society of Slovenia, Ljubljana, Slovenia

nskoric@gmail.com

ABSTRACT

This paper analyses the causes of negative public opinion on nuclear industry and current efforts to tackle it. A type of tool for tackling negative public opinion is discussed – educational nuclear power plant simulator. Influence of simulators on public opinion is discussed, with the focus on younger generations. Classification of educational simulators in context of altering public opinion is presented. For each proposed type of educational simulator, a distinct target population and aims are suggested. Several set of criteria are discussed for assessing suitability of simulator for general public: level of general education required, level of expertise in nuclear technology required, ease of use. Publicly available nuclear power plant simulators are analyzed and conforming to discussed criteria is assessed. A new educational nuclear power plant simulator is proposed. A simple implementation of such simulator is created and tested on younger members of general public.

INTRODUCTION

Nuclear industry had problems with negative public opinion since early in its history. As the time went by those problems were more or less obvious, but with ongoing Fukushima accident we are witnessing a surge in negative public opinion. This process had dire negative consequences on nuclear industry.

This paper analyzes causes and consequences of negative public opinion on nuclear industry and discusses way to fight it. Nuclear power plant (NPP) simulator is presented as one possible way. We present our own implementation of a NPP simulator named EGON.

NEGATIVE PUBLIC OPINION ON NUCLEAR ENERGY

CAUSES FOR NEGATIVE PUBLIC OPINION

Nuclear industry is less than 80 years old. Neutron, key particle of our industry was discovered in 1932, and that nuclear fission was possible was confirmed only 7 years later, in 1939, [1]. That same year World War II started, and in just few months, the project to build a atom bomb became the project of highest priority and importance for the war effort, [1].

The “Manhattan Project” was executed in greatest haste imaginable and in less than 3 years, this effort produced unseen results: nuclear reactor and atom bomb. [1]. The sheer urgency in which this great feat was undertaken was tremendous, as was secrecy, [1].

This project had a single priority: to build the bomb. All other concerns were of secondary importance, [1]. This fact, combined with considerable lack of knowledge in many areas of nuclear technology such as radiology and health physics, resulted in some serious damage to both human health and the environment, [1].

Enrico Fermi, leader of US nuclear reactor project died at the age of 53 from stomach cancer which was result of his exposure to radiation, [3].

And that is just the account of the USA. Soviet nuclear program is even heavier burden on our industry. First soviet plutonium processing plant, Chelyabinsk-40, was the site of Kyshtym disaster [4], the only ever INES 6 event, which resulted in East Urals Radioactive Trace, a heavily contaminated area of 23000 square kilometres, [5]. Reactors of RBMK design were by-product of Soviet race to atom bomb, [6]. They were designed poorly and problems with their design resulted in INES 7 event known as Chernobyl disaster.

Nuclear industry started a period of extensive growth after start of the oil crisis in 1970s, but the growth period came to an abrupt end after TMI and Chernobyl accidents, [7]. After those two events, anti-nuclear activism started exploiting mistakes that were made early in development of nuclear technology and fear of nuclear industry became mainstream.

It is today acceptable to have fear of nuclear power plants. It is acceptable to associate trefoil symbol for radioactivity with severe pollution, [8]. Children undergoing elementary education are thought that everything “nuclear” symbolizes destruction: either by nuclear explosion, or by radiation and nuclear waste.

In its infancy, nuclear industry was secretive, dirty and dangerous. It has been more than 60 years since the time of those early nuclear efforts, but consequences of those
circumstances are today still felt throughout our industry, as if nothing has changed.

Fig 1. – Nuclear trefoil is a symbol for pollution

CURRENT SITUATION

Nuclear technology today is comparatively clean and safe, [9]. While Hanford and Chelabynsk-40 reactors used open cooling loops dumping radioactive water into local waterflows [1], [4], modern power plants have 2 or 3 cooling loops and take great care that contaminated water is never released to the environment, [10]. While early nuclear facilities had a priority of building a bomb, modern power plants have a priority to pose minimal threat to public health and environment, [11].

While early reactors had no safety systems, modern plants have redundant and diverse safety systems capable of mitigating all possible accidents. Early reactors like Windscale pile which caught fire in 1957, had no emergency core cooling capabilities [12], while modern reactors multiple redundant trains of emergency core cooling systems which render events like Windscale fire impossible.

At the heart of every modern nuclear power plant design there is “defence in depth” philosophy which ensures that nuclear power plants pose no threat to general public, [11]. As a result, in 14400 cumulative reactor-years of commercial operation, Chernobyl disaster is the only commercial nuclear reactor accident in which nuclear workers or members of the public have ever died as a result of exposure to radiation, [13]. UN sponsored “The Chernobyl Forum” in 2005 declared that around 4000 deaths can be expected from radiation exposure as consequence of this accident, [14]. To put this number into perspective: there were over 42000 deaths from automobile accidents in 2006 in European Union alone [15], while tobacco smoking kills 5.4 million people in the world every year, [16].

Every industry has its share of accidents, and nuclear industry is no exception. But, given public unfamiliarity with nuclear technology, those accidents produce unreciprocally fear, [17].

CONSEQUENCES OF NEGATIVE PUBLIC OPINION

Consequences of negative public opinion on nuclear industry are numerous. Most important consequence is passage of referendum which proscribe phase-out of nuclear facilities. Nuclear industry is one of rare industries, if not the only industry, which is at times forbidden by popular vote on a referendum.

For instance, Sweden held a referendum on nuclear power in 1980. It was held in the aftermath of the Three Mile Island accident and public opinion on nuclear industry was overwhelmingly negative. Referendum had three options of which two advised fast phase-out of nuclear power plants. Those two options received over 70% of votes. Consequence of those results was decision of Swedish
parliament that NPPs in Sweden should be phased out by 2010. Referendum in Italy was held in 1987. It also was held in the aftermath of an accident: this time it was Chernobly disaster. Again, public opinion on nuclear industry was overwhelmingly negative, and results were again the same: next year, in 1988, the Italian government decided to phase out its nuclear power plants. Work on near complete Montalto di Castro NPP was terminated and two operating Italian NPPs were closed in 1990.

Parliament of Austria decided in 1978 to ban nuclear facilities for 20 years. In 1998 this ban was renewed. As opposed to Sweden and Italy, those decisions were made without referendums, albeit with full support of general public. Again, negative public opinion forced nuclear energy out of Austria.

Just those three examples show how devastating are consequences of negative public opinion. If nothing changes then Sweden, Italy and Austria are completely closed for nuclear facilities. Negative public opinion, as predecessor of this dire situation, is to be taken very seriously and more effort is needed to tackle this problem.

ONE POSSIBLE SOLUTION

In a struggle for public opinion, nuclear industry is steadily loosing ground. Anti-nuclear organisations have had formidable results even before Fukushima accident, while pro-nuclear organisations, have had low visibility and poor results in changing public opinion. We are of the opinion that more proactive approach to educating public about nuclear energy is needed.

If public is to be sensibilised to nuclear technology, then previously mentioned “veil of mystery” needs to be lifted. Ignorance and neglect for environment and human health that was prevalent while nuclear technology was in its earliest stage of development are long gone, and our industry has nothing to hide. Moreover, increased transparency of nuclear industry can only benefit both the industry and general public. By allowing more insight into the way in which nuclear facilities work, we increase public understanding of world around them to their benefit, and we increase public confidence in nuclear energy to the benefit of our industry.

Nuclear energy is as clean and as safe as any other energy generating industry, and even cleaner and safer than most, [9]. This needs to be shown to the general public, and the best way to show is to offer more information and more tools with which members of public can familiarise themselves with our industry. We have to open up more aggressively if we want to win the nuclear energy debate. After all, as we previously mentioned, we have nothing to hide.

Again, our opinion is that this “veil of mystery” can be lifted by better educating general public about nuclear technology. Producing a nuclear power plant simulator for general public is, we feel, a good step in that direction.

Earlier in this chapter we mentioned the fact that mortality in car accidents or from smoking induced illnesses is far greater than mortality from nuclear power plants. Members of general public understand, in principle, how car works and are aware of mechanisms by which smoking increases mortality. This information demystifies those two activities and fear of cars or fear of smoking are exceedingly rare.

We are of the opinion that more effort is needed to transform nuclear technology from secretive, mysterious industry into a transparent industry, one well understood by general population. This article presents one way of reaching that goal: by presenting general public with nuclear power plant simulator.

NPP SIMULATORS

INFLUENCE OF SIMULATORS ON PUBLIC OPINION

Computer simulators are ubiquitous. Simulations of various processes are used throughout wide array of human activities, including research and development, all kinds of industry applications and, of course, in computer games. Some of the most popular categories of computer games are in fact crude simulators adapted for player’s enjoyment: car racing games, first person shooters, strategic war games, sport games, etc. Some game developers even capitalise on the fact that their games are simulations: company Maxis is author of SimCity and Sims family of games which simulate a city or a person, respectively.

There is also wide array of games which aim to simulate a process as realistically as possible. Flight simulators like Microsoft Flight Simulator family of games are extremely popular example, but there are others, like submarine, cargo ship and freight train simulators. There are even such bizarre examples such as simulators of agricultural work like Farming Simulator by GIANTS software.

Existence of wide array of fictional simulators is a good illustration that simulators are extremely popular. For instance, games like Eve Online are sold in large quantities and have many players. This has led to players’ familiarity with those fictional spaceships, and it can be safely concluded that players of computer games are better acquainted with Millennium Falcon, a fictional spaceship, than with nuclear power plants.


All of those simulators help familiarise players with the process in question. Flight simulators are used in training of pilots and helping people get rid of fear of flying [17], car racing simulators familiarise young players with how automobiles are driven and military games teach players military strategy and tactics.

United States Army is well aware of this fact, which is the key idea behind their creation of game “America’s Army”. Primary aim of creating this game was to help recruitment by showing general population what it is like in military training camps. Through “America’s Army” players have the opportunity to “experience” the life of a recruit and in the process players learn a great deal about US Army. The game reached unprecedented success with hundreds of thousands of players spending millions of hours in this simulation, [18].

Previous examples clearly show that most, if not all, simulators used by general public are in fact computer games. Computer games are mostly played by younger generations, and influence of those games is greatest on younger members of general public. It is, therefore, reasonable to expect that majority of users of a NPP simulator would also be of younger age.

By designing and implementing a NPP simulator, we are, therefore, inherently targeting younger generations. This consequence is a fortunate one, since youngest generations are also most open-minded ones, and younger age is the age in which fears of nuclear industry are formed. Younger generations are general public of the future, and their opinion will be shaping public opinion in coming years. We can conclude that targeting younger generations makes a lot of sense and that NPP simulators are a good way to approach this particular part of general public.

PUBLICLY AVAILABLE NPP SIMULATORS

One notable exception to this abundance of various simulators is nuclear power plant simulators. To the best of our knowledge, there are only two freely available programs that resemble nuclear power plant simulators:

1. “Nuclear Power Plant Simulator Game” authored by Geoffrey Noles, and
2. “NuclearReactor” authored by H.-M. Prasser

Here we present brief description of both simulators.

**Nuclear Power Plant Simulator Game**

Nuclear Power Plant Simulator Game was written between 2001 and 2003 by Geoffrey Noles. The game is written in Adobe Flash and is based on algorithms written in BASIC by Stephen R. Berggren and Ivan C. Smith. The game includes an animation of typical PWR plant with most important components marked. It also has simple instructions and directions how to play the game. The game is turn based, which means that parameters do not change in real time, but only when the player presses the “GO” button.

The game allows its players to control 4 parameters:

1. Control Rod position
2. Emergency Coolant Flow
3. Primary Coolant Flow
4. Secondary Coolant Flow

The game displays values of several parameters, some of which are: rod control position, temperature of reactor, heat exchanger (steam generator) and cooling tower, power output and level, leakage and flow of emergency, primary and secondary coolant. Several alarms annunciators are also present, some of which are: primary, secondary or emergency coolant leak, primary, secondary or emergency coolant low, primary or secondary pump failure, turbine overload, reactor overheated and melt down.
controlled, but the game is unfortunately wildly unrealistic since only 3 turns are needed to reach core meltdown and containment building failure, which is, by itself, reason to consider this game harmful.

Furthermore, there is no automatic reactor trip or safety injection upon reaching certain setpoint – player has to shut down reactor manually. There is, also, no switch for manual reactor trip or safety injection actuation, so player has to manually insert the rods into the core and set the “Emergency Coolant Flow”. All of those are grave inaccuracies which paint a wrong picture of modern nuclear power plants.

Despite of its important deficiencies, game is in fact quite interesting and fun to play with. This observation gives us hope that even realistic nuclear power plant simulators can be fun to play with.

**NuclearReactor**

NuclearReactor is a Monte-Carlo simulation written by Horst-Michael Prasser, professor of nuclear energy systems at Swiss Federal Institute of Technology in Zurich. It is not in fact nuclear power plant simulator, but only nuclear reactor simulator. It includes animation of reactor core with following components:

1. fuel rods
2. control and shutdown rods
3. moderator channels
4. reflector
5. fast and thermal neutrons

The program simulates each individual neutron and displays it on the animation. Each neutron can be observed and it can be clearly seen how some neutrons escape the core as fast neutrons, some reach thermal energies and then escape the core, and some get absorbed in the fuel. The program also offers a “slow motion” mode which makes it easier to follow neutrons on the display.

The simulator gives the player several controls, some of which are: control rods in and out buttons, SCRAM button, neutron source in and out buttons and drain moderator button. There are 3 parameters displayed: neutron counts, reactor power and cumulative number of fissions in the reactor since the simulator started.

The game is played in real time and allows the player to start up the reactor, increase and decrease its power using control rods, shutdown the reactor using SCRAM button. The simulator also allows the user to do several practically impossible things such as add or remove reflector and drain the moderator and then observe response of the reactor.

The simulator requires some basic understanding of reactor physics, or a presence of a teacher which can explain basic concepts about this simulator to the user. Unfortunately, web site with instructions is presented only in German language. This program is an interesting, albeit rudimentary attempt to create a nuclear reactor simulator, but this game is also quite unrealistic, just as Nuclear Power Plant Simulator Game in the previous chapter. Although this simulator does not allow the user to melt the core, it, on the other hand, does not show prompt jumps and prompt drops and takes more than 10 seconds from moment SCRAM button is pressed to the moment reactor power is below 5%, which is highly unrealistic.

The fact that reactor trip takes so much time is one of consequences of this simulators simple model of a reactor. For instance, the model doesn’t take into account feedback effects, such as fuel and moderator temperature coefficients. Therefore, this reactor model never reaches point of adding heat (POAH) and allows different powers to be achieved with the same position of control rods. In fact, reactor is critical on only one rod position, around rod position of 60%.

Lack of feedback effects and high differential worth of control rods make holding this reactor exactly critical impossible and thus render this reactor quite unstable and hard to control. In fact, it is impossible to leave this reactor uncontrolled for more than a minute or two because it will simply slide towards high or low trip setpoints.

From these brief descriptions of publicly available nuclear power plant simulators, it is obvious that there is a lot of room for improvement. Even a simple but realistic
Simulator without important flaws that were noticed in existing simulators would be a great improvement in this field.

**DESIGNING A NPP SIMULATOR**

Since nuclear technology is comparatively complicated field, there is a wide range of possible NPP simulator designs and respective target populations. Existing simulators range from simple ones, such as Nuclear Power Plant Simulator Game described previously, to extremely complicated, such as full scope NPP simulators which include a verbatim copy of a main control room. Possible target populations range from primary school students to experienced nuclear reactor operators undergoing retraining.

To determine the design of a NPP simulator, we find it necessary to first define the target population of the simulator in question. It is obvious that simulator targeting primary school students and simulator targeting nuclear engineers cannot have the same design. Therefore, target population is one of most important determining factors in design of a simulator.

**TARGET AUDIENCES**

We have previously shown that field of NPP simulators is quite sparsely populated; therefore many types of NPP simulators are available for implementation. Some of those simulators are more useful for changing public opinion on nuclear industry, some are less useful. It is our opinion that in this wide range of possible designs, there are at least three target groups in general population which should be targeted with dedicated NPP simulators. Those groups are:

1. children
2. general public
3. engineers or students of technical sciences

In modern educational systems, environmental awareness is formed at early age. Young children are taught about benefits of recycling and littering is discouraged. As we already mentioned, it is common for children to draw nuclear trefoil symbol when expressing themselves about pollution. Giving them a tool with which they can familiarise themselves with nuclear power plants and perceive NPPs as part of everyday life could be a valuable asset in an effort to change perception of nuclear industry.

Simulator for general public targets the largest of 3 groups discussed in this chapter, and also most diverse one. They are the group which forms the public opinion which shapes government decisions regarding nuclear facilities. This group includes citizens which have the right to vote on elections and on referendums concerning nuclear energy. Most anti-nuclear activists fall into this category. Therefore, developing an NPP simulator for general public is of uttermost importance.

Most complicated NPP simulator which is still usable by a significant number of people is the one targeted at engineers and students of technical sciences. This group of potential users is the most tech-savvy of three groups discussed in this paper, but also the most susceptible to computer games. This group can be expected to be the first one to download and use a NPP simulator, therefore paving the way for other target groups to join in.

Simulator more complicated than the last proposed design would require considerable knowledge of nuclear engineering. There already exist several simulators falling into this category (for instance: PCTRAN), but this type of simulators:

1. are not freely available,
2. can hardly be used by significant part of general public;
and therefore this category of simulators falls outside of the scope of this paper.

**PROPERTIES OF A SIMULATOR**

To simplify the process of design of a NPP simulator, we find it necessary to define a set of properties of the simulator which depend on chosen target population. For instance, ease of use of a simulator is one such property: if simulator is designed for children, then it should be very easy to use; but if it is designed for nuclear engineers, it can be as complicated as necessary while still remaining practical.

While debating design of simulator proposed in this paper, we have come to conclusion that properties which designate the target population of a NPP simulator are:

1. ease of use
2. required level of education
3. level of expertise in nuclear technology

**Ease of use** can, as we mentioned previously, range from quite simple NPP simulators for children, to complex, full scope simulators for education of nuclear engineers.

**Required level of education** can be separated in several categories:

1. no education whatsoever, in case of simulators for children,
2. general secondary education for simulators for general public which require some basic understanding of physics and/or electronics, and
3. higher technical education for simulators for students of technical sciences or engineers of various fields, including nuclear.

**Level of expertise in nuclear technology** is another determining factor for design of NPP simulator. Simulator for general public mustn't
require any level of expertise in nuclear technology, while some understanding of basic concepts of nuclear technology can safely be expected from, for instance, students of technical sciences.

Regarding set of properties proposed earlier, NPP simulator for children should have these properties:
1. ease of use: very easy
2. required level of education: none
3. level of expertise in nuclear technology: none.

Obviously, very simple simulators are required for children’s use. Accent should be placed primarily on ease of use and visual attractiveness, attention to great technical detail should be a second order issue.

Regarding set of properties proposed earlier, NPP simulator for general public should have these properties:
1. ease of use: easy
2. required level of education: secondary education
3. level of expertise in nuclear technology: none.

Simulators targeting general public can be a bit more complicated than those targeting children, but still ought to be relatively simple as not to discourage users, since great motivation and persistence needed to operate complicate software cannot be expected from members of general public. Some basic understanding of physics and/or electro-technics can be expected, but quite basic indeed, since secondary education does not supply students with very deep understanding of physical phenomena. To assume no understanding of nuclear technology is the most conservative approach possible, and we are of the opinion it should be pursued in this target population.

Regarding set of properties proposed earlier, NPP simulator for engineers should have these properties:
1. ease of use: arbitrary
2. required level of education: technical university level education
3. level of expertise in nuclear technology: basic concepts.

Unlike with members of general public, this group of potential users can be expected to input a certain amount of effort in mastering the game controls, so ease of use should not be the primary concern. This target group can be also expected to have some basic understanding of nuclear technology, since most technical university programs include basic mechanics, thermodynamics, hydrodynamics, nuclear physics, electro-technics and similar subjects which for the foundation of nuclear technology. Also, members of this population are more likely to already have researched some basic concepts of how nuclear facilities work.

EGON NUCLEAR POWER PLANT SIMULATOR

MOTIVATION

In previous chapters, we have shown that:
1. circumstances surrounding early development of nuclear technology created impression that nuclear technology is secretive, dirty and dangerous,
2. nuclear energy is today clean and safe, but negative impressions still exist and are very strong,
3. one possible way of changing this impressions is by educating the public and thus increasing transparency of nuclear industry,
4. one possible way of educating the public is by usage of nuclear power plant simulators.

In this chapter we discuss our own nuclear power plant simulator named EGON.

TARGET AUDIENCE

As discussed in previous chapter, first decision to be made when designing a NPP simulator is defining the target audience. We have decided to design a simulator targeting the third group proposed: engineers or students of technical sciences.

This decision is founded on several observations. First, such simulator is most straightforward to implement. This might seem like a unrealistic observation, but during phase of initial research for this project, we concluded that resources on simulating nuclear processes are abundant, and almost all of existing research concerns detailed simulation of nuclear processes. We were unable to find any research into simple simulators of nuclear power plants such as simulators for children or web-games simulating nuclear power plant. Therefore, the decision to implement a very simple NPP simulator implies entering an unexplored field.

On the other hand, decision to implement a more complicated, and therefore more exact simulation, gives us the possibility to use some tools and knowledge already developed, therefore making the implementation easier. For instance, we can use existing models of reactor core implemented in RELAP or some other simulating tool. Embedding already existing but complex model of reactor core into a simulator for school children makes very little sense.

Second, by creating a simulator for engineers, we open the possibility that some of users of the simulator might be interested in aiding its development. An NPP simulator is a serious undertaking, and influx of new
contributors to this project would be greatly appreciated. It is not very likely that some computer science graduate would consider improving an NPP simulator for children as a part of his diploma project. On the other hand, it is quite possible that such person would be motivated to contribute to a simulator which is complicated enough to be interesting.

Third, it is easier to simplify a simulator than to make it more complicated. For instance, it is quite easy to program a simple routine to handle actions deemed too complicated for general public, such as handling Chemical and Volume Control System (CVCS), or reactor startup because every NPP has procedures for handling those systems which can be easily translated to a computer program. On the other hand, if a simulator is designed as a simple one, and then it is made more complicated, it includes changing fundamental design principles, which is neither simple nor advisable.

Therefore, it will be easier to transform a simulator for engineers into a simulator for general public, than it would be to transform a simple simulator for general public into a more complicated and more detailed simulator for engineers.

**DESIGN**

EGON NPP simulator is designed as a concurrent program composed of a set of parallel nodes. Each node maps a specific subsystem of an NPP. Several nodes are then grouped in super-nodes which simulate a group of subsystems, that is: a part of a NPP. For instance, current implementation of EGON consists of nodes which represent following systems: reactor core, rod control system, reactor make-up system, W7300 and turbine. Those nodes are then grouped in super-node called “reactor”. Apart from reactor super-node, we also have a “turbine” super-node which, for instance, has a sub-node “ramper”, which is used for increasing or decreasing turbine power.

Nodes communicate between themselves values of their parameters. For instance, “rod control system” node requests value of \( T_{\text{REF}} \) parameter from “W7300” module. “W7300” module then requests value of turbine power parameter from “turbine” super-node, calculates \( T_{\text{REF}} \) and then sends it back to “rod control system” node.

Each node is, also, capable of sending its parameters to an “indicator” node which is used as an interface with the outside world. When a user wants to know, for instance, rod position, then graphical user interface requests value of rod position from the “indicator” node, which then communicates with rod control system and retrieves the value.

This modular design has one important advantage: it allows for reimplementation of a single module without this reimplementation affecting other modules. In practice this means that we can change our implementation of, for instance, reactor core and keep only interfaces to other modules. Modular design allows us to keep implementations of other plant systems unchanged. Another possibility is fragmentation of systems: we can replace, for instance, node which implements reactor core with one super-node which controls a number of nodes each implementing one fuel assembly. That way we get a more detailed simulation, again, without affecting other plant systems.

First versions of EGON were implemented in Python programming language, but during preliminary development it was discovered that concurrent design we envisaged calls for a more concurrency-oriented developing environment. Erlang/OTP is a development platform oriented on concurrent and distributed applications, therefore, programming language was early on switched to Erlang/OTP. Some Python code is still present (primarily I/O functionality for reading configuration files), but it is due to be reimplemented in Erlang for reasons of speed.

There are several reasons why Erlang/OTP (commonly referred as just “Erlang”) was chosen over Python, or other languages with build in concurrency support like Scala or Glasgow Haskell Compiler. Most important reason is: Erlang is a very reliable system used in industrial applications where availability and reliability are primary objectives. Applications implemented in Erlang are known to work for years without a second downtime. This feature of Erlang allows us to build a simulator with very little maintenance requirements.

Second advantage of using Erlang/OTP is its built in implementation of wide array of communication protocols, which are extremely easy to use. This allows us to have simulator on one server, and graphical user interfaces (GUIs) on some other computer. For instance, an instructor can set up a server on his computer, and students can open GUIs and access the same simulation on their own computers.

Third feature of Erlang/OTP platform is its integration with other technologies. Erlang/OTP makes it easy to implement some nodes in languages other than Erlang. Thanks to this feature of Erlang, it is easy to create heterogeneous implementation using several programming languages with Erlang/OTP as base technology. As we previously mentioned, some nodes in EGON remain implemented in Python. Similarly, while Erlang/OTP is excellent for implementing concurrency related parts of simulator such as inter-node communication,
starting or stopping of nodes, etc., it is obvious that some parts of simulator would be better off if implemented in technologies aimed at the problem in question. For example, Erlang/OTP graphical user interface (GUI) capabilities are quite weak, therefore we decided to implement GUI in C#. Furthermore, there already exist some excellent nuclear simulating frameworks like RELAP which could possibly do a better job simulating reactor core than our own implementation. Erlang allows us to do just that: replace our implementation of reactor core with RELAP model. Also, if any developer decides to contribute to our project using technology other than Erlang/OTP, this can be easily done.

Final advantage of using Erlang/OTP platform is out-of-the-box scalability which Erlang provides. In case that this simulator advances in complexity, surpasses its initial design to be just education simulator and becomes a full scale NPP simulator and therefore so CPU intensive that running it would require more than one server, Erlang provides us with tools to migrate this simulator to distributed environment seamlessly.

STATUS OF THE PROJECT

Current status of the project is early alpha stage. Simulator presented here is result of two months of on-and-off development in our free time so results are far from spectacular, on the contrary.

EGON Simulator allows user to simulate very simple transients like: changing turbine power, moving control rods, borating or diluting primary coolant and observing parameters like turbine power, reactor power, $T_{AVG}$, $T_{REF}$, rod position and boron concentration.

Currently simulated systems are: reactor core, rod control, reactor makeup, W7300 process cabinets and turbine. All of those systems are implemented in most crude and simple ways. For instance, nuclear flux is changing according to turbine power, without any delays. Steam generators are completely omitted from simulation.

The simulator has been used by nuclear engineers, members of “engineers or students of technical sciences” target group, and by members of general public. Preliminary results show that, although nuclear engineers show great enthusiasm when using EGON, it is still not ready enough to entice deeper interest in members of “engineers or students of technical sciences” target group. EGON in its current state is still to complicated for usage by members of general public. Valuable feedback is received from these evaluations, and this feedback will be taken in account when further design decisions will be made.

EGON NPP simulator is licensed under GNU General Public License version 3 or greater which makes it free software and it is thus quite easy to contribute to this project.

We consider current implementation to be a simple proof of concept which can be used as a good basis for further development.

Current implementation of EGON simulator and related tools is available at web address https://github.com/egon-sim/.
FUTURE PLANS

Our first concern in this stage of development is expanding the model. Priority is including most important parts of the power plant into the simulation, such as steam generators, reactor coolant pumps and CVCS. More accurate reactor core model is the next priority, and then improving graphical user interface.

Long term plans include adding emergency core cooling system, support systems like component cooling, essential service water and turbine-generator support systems.

After completing first cycle of development, we plan to implement web based user interface which can then be integrated into social networks like Facebook. Providing nuclear power plant simulator on Facebook is one of our primary motivations for this project, since such a project would be possibly one of the best way, if not the best way, to popularise nuclear technology.

CONCLUSION

Using NPP simulators for tackling negative public opinion is an unexplored field, but one in which we see a great potential. Simulators have previously already been successfully used in similar situations, such as fighting fear of flying. We hope that NPP simulators can help educate general public and thus reduce mounting negative opinion on nuclear industry.

EGON, a NPP simulator aimed at engineer and students of technical sciences, is in its earliest stages of development, but is quickly approaching level of usability of already existing freely available NPP simulators. As we will be further developing EGON NPP simulator, we do hope our results will encourage more research and development in this direction.

REFERENCES

[16] The New Your Times “Smoking deaths could hit a billion”; quoting Douglas Bettcher, head of the World health Organisation's Tobacco Free Initiative
[18] Zhan, L. “The Potential of America's Army Video Game as Civilian-Military Public Sphere”