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Panduan dan
Profil Penghargaan

Siwabessy Award dan G.A. Siwabessy Memorial Lecture Tahun 2024

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KATA PENGANTAR

Badan Riset dan Inovasi Nasional (BRIN) bekerja sama dengan Lembaga Pengelola Dana Pendidikan (LPDP) merasa perlu untuk memberikan penghargaan tertinggi secara berkelanjutan kepada perorangan yang berasal dari internal maupun dari eksternal BRIN. Siwabessy Award adalah suatu penganugerahan yang merupakan salah satu bentuk apresiasi BRIN kepada insan dan tokoh (perusahaan, industri, akademisi, profesional) yang sudah berkecimpung dan menghasilkan berbagai prestasi maupun inovasi yang temuannya sangat luar biasa dan menaruh perhatian khusus dalam dunia ketenaganukliran di Indonesia. Sementara itu, G.A. Siwabessy Memorial Lecture merupakan suatu kegiatan keilmuan dalam bentuk orasi ilmiah yang disampaikan oleh individu yang berjasa dalam penemuan, pengembangan, dan penyebarluasan di bidang ilmu pengetahuan dan ketenaganukliran, serta memiliki kontribusi bagi masyarakat dan bangsa Indonesia.

Kami mengucapkan terima kasih kepada seluruh pihak yang telah mendukung terselenggaranya kegiatan Siwabessy Award dan Memorial Lecture Tahun 2024.

Jakarta, 10 Desember 2024

Panitia

PENDAHULUAN

Prof. Dr. Gerrit Augustinus Siwabessy (G.A. Siwabessy) adalah salah satu radiolog pertama di Indonesia. Pada tahun 1954, bangsa Indonesia khawatir dengan adanya percobaan-percobaan senjata nuklir di wilayah Pasifik setelah terjadinya Perang Dunia ke-2. Presiden Soekarno saat itu menunjuk G.A. Siwabessy sebagai ketua panitia negara untuk melakukan penyelidikan radioaktivitet untuk mengetahui apakah Indonesia terkontaminasi debu radioaktif dari percobaan nuklir di Pasifik. Saat itu, dilakukanlah penyelidikan di wilayah timur Indonesia dan ternyata tidak ditemukan adanya kontaminasi terhadap debu radioaktif tersebut.

G.A. Siwabessy sangat aktif terhadap perkembangan kenukliran hingga diketahui bahwa pemanfaatan nuklir tidak hanya untuk persenjataan atau energi saja, tetapi untuk berbagai macam bidang seperti bidang kesehatan, bidang pertanian, bidang peternakan, bidang lingkungan, dan lain sebagainya.

Dengan memperhatikan perkembangan pendayagunaan dan pemanfaatan tenaga atom bagi kesejahteraan masyarakat, pada tanggal 5 Desember 1958 melalui Peraturan Pemerintah Nomor 65 tahun 1958, dibentuklah Dewan Tenaga Atom dan Lembaga Tenaga yang kemudian disempurnakan menjadi Badan Tenaga Atom Nasional (BATAN) berdasarkan Undang-undang Nomor 31 tahun 1964 tentang Ketentuan-Ketentuan Pokok Tenaga Atom. Pada tahun 1964, Presiden Soekarno menunjuk G.A. Siwabessy untuk menjabat sebagai Menteri Badan Tenaga Atom Nasional dan pada tahun 1966 juga ditunjuk sebagai Menteri Kesehatan Republik Indonesia.

Sebagai bentuk apresiasi atas jasa-jasa G.A. Siwabessy terhadap perkembangan kenukliran, Badan Riset dan Inovasi Nasional (BRIN) sebagai lembaga pemerintah yang

menjalankan fungsi penelitian, pengembangan, pengkajian, dan penerapan, serta invensi dan inovasi yang terintegrasi akan menyelenggarakan Siwabessy Award dan G.A. Siwabessy Memorial Lecture Tahun 2024. Siwabessy Award adalah suatu penganugerahan yang merupakan salah satu bentuk apresiasi BRIN kepada insan dan tokoh (perusahaan, industri, akademisi, profesional) yang sudah berkecimpung dan menghasilkan berbagai prestasi maupun inovasi yang temuannya sangat luar biasa dan menaruh perhatian khusus dalam dunia ketenaganukliran di Indonesia. Sementara itu, G.A. Siwabessy Memorial Lecture merupakan suatu kegiatan keilmuan dalam bentuk orasi ilmiah yang disampaikan oleh individu yang berjasa dalam penemuan, pengembangan, dan penyebarluasan di bidang ilmu pengetahuan dan ketenaganukliran, serta memiliki kontribusi bagi masyarakat dan bangsa Indonesia.

Kegiatan Siwabessy Award dan Memorial Lecture adalah penghargaan dan orasi ilmiah dari seorang insan, tokoh, ilmuwan, dan pakar yang telah memberikan sumbangsih nyata dan bermanfaat bagi ilmu pengetahuan dan kemanusiaan. G.A. Siwabessy Memorial Lecture pertama kali dilaksanakan oleh BRIN tahun 2022. Adapun nama pemberi orasi ilmiah Memorial Lecture sebelumnya, yaitu:

1) Prof. Dr. Muhayatun, M.T., Badan Riset dan Inovasi Nasional (BRIN), yang menyampaikan orasi ilmiah pada G.A. Siwabessy Memorial Lecture Tahun 2022 dengan judul Pemanfaatan Teknik Analisis Nuklir untuk Penguatan Riset di Bidang Lingkungan dan Kesehatan.
2) DR.-ING. Yuliang Sun, Institute of Nuclear and New Energy Technology – Tsinghua University, yang menyampaikan orasi ilmiah pada G.A. Siwabessy Memorial Lecture Tahun 2023 dengan judul *The Develompent of High Temperature Gas-Cooled Reactor Technology in China.*

Tujuan

Tujuan diselenggarakannya Siwabessy Award dan G.A. Siwabessy Memorial Lecture adalah untuk:

1) Memberi apresiasi bagi individu yang telah berjasa dalam penemuan, pengembangan, dan penyebarluasan di bidang ilmu pengetahuan dan ketenaganukliran;
2) Mewujudkan sumber daya manusia Indonesia unggul yang mampu menguasai, mengembangkan dan menyebarluaskan ilmu pengetahuan dan ketenaganukliran untuk kesejahteraan bangsa Indonesia;
3) Mendorong masyarakat turut serta mengembangkan ketenaganukliran di berbagai bidang.

Penerima Manfaat

Penerima manfaat Siwabessy Award adalah periset yang berjasa dalam penemuan, pengembangan, penyebarluasan ilmu pengetahuan dan teknologi (iptek) serta memiliki dampak serta kontribusi bagi masyarakar dan bangsa Indonesia di bidang ilmu pengetahuan dan ketenaganukliran.

Penerima manfaat G.A. Siwabessy Memorial Lecture adalah individu atau tokoh yang memberikan inspirasi dalam penyebarluasan ilmu pengetahuan di bidang ketenaganukliran serta memiliki kontribusi bagi masyarakat dan bangsa Indonesia.

Waktu dan Tempat

Kegiatan Siwabessy Award dan G.A. Siwabessy Memorial Lecture Tahun 2024 diselenggarakan pada:

Hari/Tanggal : Kamis, 5 Desember 2024

Waktu : 09.00 – 12.00 WIB

Bertempat : Auditorium Sumitro Djojohadikusumo
Gedung B.J. Habibie, Lantai 3
Jalan M.H. Thamrin No. 8, Jakarta Pusat

Kriteria Pemilihan

Kriteria Pemilihan Siwabessy Award dan G.A. Siwabessy Memorial Lecture, sebagai berikut:

1) Memiliki integritas yang tinggi kepada Negara Kesatuan Republik Indonesia;
2) Memberikan kontribusi yang berpengaruh terhadap perkembangan ilmu pengetahuan dan teknologi (iptek);
3) Aktif memberikan sosialisasi dan motivasi yang tinggi kepada masyarakat untuk menekuni bidang ilmu pengetahuan dan teknologi yang dikembangkannya; dan
4) Tokoh yang memberikan inspirasi dalam penyebarluasan ilmu pengetahuan dan teknologi, serta memiliki kontribusi bagi masyarakat dan bangsa Indonesia.

RUNDOWN TENTATIVE PENYELENGGARAAN SIWABESSY AWARD DAN G.A. SIWABESSY MEMORIAL LECTURE

Jakarta, 5 Desember 2024

Waktu	Agenda
08.30–09.30	Registrasi
09.30–09.50	Pembukaan Acara
09.50–09.55	Pemutaran Video Profil Siwabessy Award dan G.A. Siwabessy Memorial Lecture
09.55–10.00	Pembacaan dan Penayangan Rekam Jejak Riset Pemberi Kuliah Ilmiah G.A. Siwabessy Memorial Lecture Tahun 2024
10.00–10.15	Kuliah Ilmiah G.A. Siwabessy Memorial Lecture Tahun 2024
10.15–10.25	Pembacaan dan Penayangan Rekam Jejak Riset Penerima Siwabessy Award Tahun 2024
10.25–10.30	Penyerahan Medali dan Foto Bersama kepada Penerima Siwabessy Award dan Pemberi Kuliah Ilmiah G.A. Siwabessy Memorial Lecture Tahun 2024
10.30–10.35	Sambutan Kepala BRIN
10.35–11.50	Bincang Ekosistem Riset Inovasi Dirgantara Nasional
11.50–12.00	Penutup

PROFIL PENGHARGAAN SIWABESSY AWARD DAN G.A. SIWABESSY MEMORIAL LECTURE TAHUN 2024

PROFIL PENERIMA
SIWABESSY AWARD TAHUN 2024
ZAKI SU'UD

KONTRIBUSI PADA PERSIAPAN SUMBER DAYA MENGHADAPI ERA ENERGI NUKLIR DI INDONESIA

Zaki Su'ud

1. PENDAHULUAN

Mempersiapkan sumber daya dalam menghadapi era nuklir sangat penting mengingat sistem energi nuklir merupakan sistem kompleks yang menuntut banyak persyaratan, baik dari sisi perangkat yang mendukung maupun sumber daya manusia yang terkait. Penulis mendapat tantangan ini saat akan melamar menjadi dosen di Institut Teknologi Bandung (ITB). Saat itu, pembimbing yang sekaligus pimpinan departemen memberikan tantangan untuk terjun menekuni analisis dan desain PLTN bila ingin menjadi dosen di Fisika ITB. Sebagai tindak lanjut, penulis mempelajari sejumlah referensi terkait analisis dan simulasi PLTN dengan mempelajari sejumlah buku teks yang relevan dan kemudian membuat simulasi sederhana terkait analisis netronik reaktor nuklir.

Selanjutnya, penulis meneruskan studi S2 dan S3 di Department of Nuclear Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology, Jepang dan menamatkan Pendidikan S2 dan S3 pada tahun

1995. Dalam studi S2 dan S3 tersebut, penulis meneliti PLTN generasi IV dari jenis reaktor pembiak berpendingin logam cair (*liquid metal cooled fast breeder reactor*/LMFBR), khususnya yang berpendingin sodium cair dan Pb/Pb-Bi cair. Pada saat itu, penulis berhasil mengembangkan sejumlah program komputer untuk menyimulasikan program multigrup difusi dan burnup 2 dan 3 dimensi dengan beberapa tipe geometri, program analisis thermal hidrolika, dan program untuk analisis kecelakaan jenis kehilangan daya pompa tanpa proteksi (*unprotected loss of flow*/ULOF), kecelakaan reaktivitas tanpa proteksi (*unprotected rod runout transient overpower*/UTOP), dan kecelakaan hilangnya sistem pembuang panas tanpa proteksi (*unprotected loss of heat sink*/ULOHS). Selain itu, juga dikembangkan program analisis kecelakaan pemblokan local (*local blockage accident*) yang dipicu transisi fasa dari air ke padat di sebagaian kanal pendingin.

Sekembalinya dari studi di Jepang, penulis berkontribusi mengembangkan pendidikan dan penelitian dalam bidang sains dan teknologi nuklir di ITB. Selain mengembangkan jalur penelitian terkait analisis dan desain PLTN generasi maju, penulis juga mengembangkan sejumlah aspek yang mendukungnya. Banyak mahasiswa bimbingan S1, S2, dan S3 penulis yang saat ini menjadi dosen dan peneliti, baik di dalam maupun di luar negeri, dan turut berkontribusi pada persiapan menyongsong era nuklir. Kerja sama juga dikembangkan dengan BATAN (sekarang ORTN-BRIN), BAPETEN, dan perguruan tinggi lain yang melakukan penelitian dalam bidang PLTN generasi maju, seperti Universitas Gadjah Mada, Universitas Andalas, Universitas Sriwijaya, Universitas Lampung, Universitas Jember, dan lain-lain.

Dalam bidang riset, sejumlah program komputer berhasil dikembangkan, baik yang dirintis sewaktu studi S2 dan S3 di Jepang maupun yang dibangun dari awal. Selain itu, penulis bersama kolega merintis seminar nasional dan juga internasional, khususnya seri *International Conference*

on Advances in Nuclear Science and Engineering (ICANSE) yang dimulai tahun 2007 di Hotel Grand Aquila di Bandung, lalu dilanjutkan 2009 juga di Hotel Grand Aquila Bandung, tahun 2011 dan 2013 di Bali, lalu tahun 2018 di ITB. Prosiding konferensi International ICANSE dipublikasikan di AIP Conference Proceedings dan IOP Journal of Physics Conference Proceedings. Setelah jeda karena pandemi, ICANSE 2024 kembali diselenggarakan di ITB.

Selama kariernya sampai saat ini, telah dipublikasikan 228 paper di jurnal dan prosiding internasional terindeks Scopus, serta lebih dari 100 publikasi lain. Jumlah mahasiswa bimbingan yang telah lulus sekitar 160 orang, terdiri dari 25 mahasiswa S3, 60 mahasiswa S2, dan 75 mahasiswa S1. Selain itu, untuk mendukung penelitian telah dikembangkan fasilitas komputasi yang pada saat ini terutama berupa sejumlah komputer klaster untuk mendukung komputasi parallel khususnya untuk penelitian dengan program komputer Monte Carlo, seperti kode computer MCNP6, Open MC, dan sebagian program bagian dari SCALE. Menjadi tantangan tersendiri untuk menyediakan dan memelihara komputer klaster ini karena adanya regulasi yang ketat dari dana riset yang membatasi pembelian komputer klaster secara langsung sehingga pembelian dilakukan terhadap komponen-komponen komputer klaster dan kemudian dirakit sendiri menjadi komputer klaster.

2. KODE KOMPUTER UTAMA YANG BERHASIL DIKEMBANGKAN

Secara umum ada lima kelompok kode computer utama yang berhasil dikembangkan, yaitu program multigrup difusi dan burnup 2 dimensi R-Z, program multigrup difusi dan burnup 3 dimensi R-T-Z dan X-Y-Z, program analisis kecelakaan PLTN untuk LMFBR (kecelakaan ULOF, UTOP dan ULOHS) 2 dimensi R_Z, program analisis kecelakaan 3 dimensi R-T-Z untuk ULOF, UTOP, ULOHS dan kecelakaan pemblokan local (*local blockage*), serta program simulasi

untuk perhitungan PLTN dengan skema burnup Modified CANDLE.

2.1 Program multigrup difusi dan burnup 2 dimensi R-Z dan 3 Dimensi R-T-Z serta X-Y-Z

Program multigrup difusi dan burnup 2 dimensi dengan geometri R-Z dikembangkan dengan model persamaan multigrup difusi yang didiskritisasi dan dipecahkan dengan model iterasi dalam - iterasi luar. Iterasi dalam dipecahkan dengan metoda SOR, sedangkan iterasi luar dipecahkan melalui *power method* dengan ekstrapolasi. Program ini dapat bekerja dengan data grup konstan yang berasal dari SLAROM ataupun SRAC. Data SLAROM berupa konstanta grup mikroskopis, sedangkan SRAC berupa konstanta grup makroskopis. Program ini dapat menghasilkan keluaran berupa data faktor multiplikasi sebagai fungsi waktu, *breeding ratio*/*conversion ratio* sebagai fungsi waktu, level burnup sebagai fungsi waktu, distribusi daya sebagai fungsi waktu (setiap kali perhitungan ulang program multigrup difusi), kerapatan atom sebagai fungsi waktu, spektrum energi, dan sejumlah parameter lain.

Program multigrup difusi dan burnup 3 dimensi dengan geometri R-T-Z dan X-Y-Z dikembangkan dengan model persamaan multigrup difusi yang didiskritisasi dan dipecahkan dengan model iterasi dalam - iterasi luar seperti halnya pada kasus 2 dimensi. Iterasi dalam dipecahkan dengan metoda SOR, sedangkan iterasi luar dipecahkan dengan *power method* dengan ekstrapolasi. Program ini juga dapat bekerja dengan data grup konstan yang berasal dari SLAROM ataupun SRAC. Data SLAROM berupa konstanta grup mikroskopis, sedangkan dari SRAC berupa konstanta grup makroskopis. Secara umum, fitur keluaran hampir sama dengan program difusi-burnup 2 dimensi. Contoh-contoh hasil penggunaan program simulasi tersebut dalam riset dapat dilihat pada contoh publikasi berikut.

Pada penelitian, perhitungan dilakukan dengan program multigrup difusi dan burnup 2 dimensi R-Z dengan grup konstan dari kode komputer SRAC dan SLAROM. Program ini juga digunakan dalam penelitian yang penulis lakukan dalam kerja sama CRP IAEA bertajuk "Small Reactor Without on-Site Refueling" di awal dekade 2000-an. Kegiatan ini menghasilkan desain untuk PLTN sangat kecil yang penulis beri nama Small Pb-Bi Cooled Non Refueling Nuclear Reactors (SPINNOR) dan Very Small Pb-Bi Cooled Non Refueling Nuclear Reactors (VSPINNOR).

2.2 Program Analisis Kecelakaan PLTN 2 dan 3 Dimensi

Program analisis kecelakaan ini dibuat untuk kasus kehilangan daya pompa tanpa proteksi (ULOF), kecelakaan reaktivitas (misal karena terangkatnya batang kendali) tanpa proteksi (UTOP), dan kehilangan fungsi pembuangan panas (ULOHS). Program ini merupakan gabungan program analisis *space-time kinetic* dengan model adiabatik dengan transien thermal hidraulik untuk keseluruhan teras reaktor. Program analisis kecelakaan dikembangkan dalam versi 2 dimensi dan 3 dimensi. Untuk versi 2 dimensi digunakan geometri R-Z silinder dan merupakan gabungan program perhitungan difusi dan burnup 2 dimensi, program perhitungan thermal hidraulik untuk keadaan tunak 2 dimensi R-Z, dan program *space-time kinetic* dengan model adiabatik 2 dimensi R-Z serta program transien thermalhidraulik 2 dimensi R-Z. Kode computer ini bisa digunakan untuk analisis kecelakaan ULOF yang dipicu kegagalan sebagian pompa atau keseluruhan pompa, kecelakaan UTOP akibat insersi reaktivitas positif, kecelakaan ULOHS akibat kegagalan sistem pendiingin sekunder, serta kombinasi dari ketiga kecelakaan tersebut. Contoh penggunaan program tersebut adalah pada publikasi berikut ini.

Untuk proses analisis kecelakaan, setelah perhitungan keadaaan tunak, analisis kecelakaan dimulai dengan inisiasi kondisi kecelakaan sesuai jenis kecelakaan yang akan

disimulasikan. Selanjutnya dilakukan perhitungan analisis transien aliran pendingin di sistem pendingin primer, diikuti dengan perhitungan distribusi panas di bahan bakar, cladding dan pendingin di seluruh bagian teras reaktor. Berikutnya dilakukan perhitungan analisis thermal hidraulik di tanki panas, pembangkit uap (steam generator) dan tanki dingin. Tahap berikutnya adalah perhitungan umpan balik reaktivitas dengan menggunakan teori gangguan menggunakan fluks netron dan adjoint flux neutron dari hsil perhitungan multigrup difusi. Selanjutnya dilakukan perhitungan kinetika ruang waktu untuk mencari fungsi amplitude dan fungsi bentuk yang baru (fungsi bentuk dihitung dengan selang waktu yang lebih lama dari fungsi amplitudo). Berikutnya dilakukan perhitungan jatuh tekanan di keseluruhan sistem. Simulasi kemudian masuk ke iterasi berikutnya dengan perhitungan Kembali aliran pendingin di teras reaktor, dan seterusnya.

Untuk analisis kecelakaan 3 dimensi dilakukan dengan geometri R-T-Z dan selain untuk silusasi UTOP, ULOF dan ULOHS juga dapat digunakan melakukan simulasi analisis pemblokan local akibat membekunya bahan pendingin di sebagian kanal pendingin.

2.3 Pengembangan Program Simulasi Modified CANDLE (MCANDLE)

Perhitungan Modified CANDLE dapat dikategorikan dalam 2 jenis, yaitu perhitungan untuk mencari kondisi kuasi ekuilibrium dan perhitungan untuk simulasi *start-up* Modified CANDLE. Untuk program simulasi quasi ekuilibrium MCANDLE diperlukan proses iterasi yang melibatkan program perhitungan multigrup difusi dan burnup dan program untuk menghasilkan konstanta grup yang diperlukan. Skema MCANDLE juga mempunya beberapa variasi terkait arah *shuffling* bahan bakarnya, ada MCANDLE aksial, MCANDLE radial, dan MCANDLE kombinasi aksial-radial.

Program perhitungan MCANDLE terdiri dari sejumlah program yang dikendalikan dengan C shell linux untuk mengontrol proses iterasinya. Program pertama adalah program multigrup difusi dan burnup yang ditambahkan fitur menghitung kerapatan daya sesuai perhitungan MCANDLE. Selanjutnya ada program yang mengekstrak hasil perhitungan SRAC/SLAROM untuk diintegrasikan pada perhitungan iterasi MCANDLE.

Tinjau sistem MCANDLE dengan 10 region dan 10 tahun pereode operasi. Bahan uranium alam awalnya dimuat di region 1. Setelah burnup 10 tahun dipindahkan ke region 2, setelah 10 tahun burnup berikutnya dipindahkan dari region 2 ke region 3 dan seterusnya. Region 1 dipilih letaknya dekat region yang aktif (misal 10 atau 9 agar ada akselerasi akumulasi plutonium selama pereode burnupnya. Untuk perhitungan kuasistatik kerapatan daya tiap region ditebak dahulu nilainya lalu dilakukan perhitungan sel bahan bakar misal dengan SRAC. Selanjutnya hasil perhitungan konstanta grup digunakan oleh program multigrup difusi dan burnup untuk melakukan analisis difusi dan burnup. Sebagai hasilnya diperoleh data kerapatan daya tiap region yang kemudian digunakan untuk memperbaharui perhitungan konstanta grup. Demikian dilakukan iterasi sampai konvergen.

Untuk hasil simulasi skema burn-up MCANDLE ada peningkatan level burnup di 10 tahun pertama karena posisi bahan bakar yag dekat region 10 yang merupakan region sangat aktif. Selain itu peningkatan burnup yang signifikan muncul kira-kira setelah separuh pereode Sejarah waktu burnup yaitu setelah bahan bakar masuk ke region pembakaran (*burning region*).

3. HASIL-HASIL RISET YANG UTAMA

3.1 Pengembangan Reaktor berumur Panjang tanpa pengisian ulang bahan bakar selama operasi

Penelitian ini merupakan lanjutan dari penelitian tentang PLTN generasi IV yang dilakukan selama studi S2 dan S3 namun jenis PLTN yang digunakan dan karakteristiknya mengalami perluasan. Pada penelitian S2 dan S3 di Jepang, cakupannya adalah reaktor modular 100–150MWt berpendingin sodium, Pb, atau Pb-Bi cair dengan bahan bakar jenis nitrida.

Sekembalinya ke Indonesia, penulis memperluas cakupan penelitian tentang PLTN berumur panjang tanpa pengisian ulang bahan bakar yang memiliki fitur keselamatan inheren. Perluasan ini mencakup spektrum daya mulai dari orde beberapa MWt sampai orde ribuan MWt. Selain itu, konsep ini juga diterapkan pada PLTN berpendingin air ringan yang termasuk generasi III/III+, khususnya dengan menggunakan siklus bahan bakar Thorium- U-233. Perluasan lain adalah dengan mengembangkan PLTN generasi lanjut berbasis reaktor cepat berpendingin gas helium (GCFR/GFR)

Dari hasil tersebut, syarat penting untuk mencapai umur panjang adalah pengaturan rasio konversi internal sebaik mungkin. Ini dilakukan dengan mengatur fraksi volume bahan bakar, persentase bahan fisil, dan juga rasio moderasi untuk reaktor termal. Pemilihan jenis bahan bakar dan siklusnya juga penting untuk mencapai rasio konversi internal yang mendekati satu.

3.2 PLTN dengan skema burnup Modified CANDLE

PLTN dengan skema bahan bakar MCANDLE merupakan salah satu jalur penelitian penulis yang cukup banyak dilakukan. Penelitian ini berfokus untuk menganalisis kemungkinan penggunakan skema burnup MCANDLE untuk berbagai tipe reaktor serta proses optimasinya misal untuk mendapatkan level burnup keluaran yang minimal, untuk

mendapat ekses reaktivitas yang tak terlalu besar, dan sebagainya. Contoh contoh hasil dapat dilihat pada contoh publikasi berikut.

Hasil-hasil penelitian kami menunjukkan bahwa Pb-208 memiliki keistimewaan untuk aplikasi MCANDLE ukuran kecil karena mendukung teras dengan kekritisan tinggi. Dengan demikian pendingin ini juga potensial digunakan untuk mengejar Tingkat burnup yang relatifrendah agar dapat menggunakan bahan struktur yang tersedia. Penelitian ini juga menunjukkan bahwa skema MCANDLE aksial-radial menghasilkan konfigurasi teras yang memiliki daya kekritisan tinggi. Ini sangat ideal digunakan untuk merancang reaktor MCANDLE berukuran kecil dan yang ingin mengejar level burnup keluaran yang relative rendah.

3.3 Penelitian Korosi Pb-Bi dengan Simulasi Molecular Dynamics

Salah satu kendala PLTN berpendingin Pb/Pb-Bi cair adalah masalah korosi yang menimpa bahan structural yang bersinggungan dengan bahan pendingin Pb-Bi/Pb cair ini. Sejauh ini, telah ada metode praktis untuk menekan korosi ini dengan mengontrol kadar oksigen dalam pendingin tersebut. Namun, hal ini baru sebatas hasil eksperimen saja; belum didukung analisis teoritis yang kuat. Kami memulai penelitian ini secara komputasional dan setelah melalui 2 penelitian doctoral berhasil membuktikan pertama kali di dunia bahwa secara teoritis/komputasional menggunakan metoda molecular dinamik dengan kode komputer MOLDY. Hasilnya telah dipublikasikan di sejumlah jurnal internasional.

4. HASIL-HASIL LAIN

Masih banyak lagi hasil-hasil yang telah dicapai penulis yang tak memungkinkan dijabarkan secara rinci dalam risalah ini. Hasil-hasil ini meliputi penelitan terkait PLTN LWR (PWR dan BWR) dengan karakteristik umur yang panjang dan

ekses reaktivitas yang rendah dengan menggunakan siklus Thorium. Selanjutnya, terkait reaktor fusi nuklir jenis tokamak sejumlah penelitan terkait material *first wall* telah banyak dilakukan simulasi dan optimasi menggunakan MCNP6. Juga telah dipecahkan persamaan Grad-Savranov secara numerik untuk plasma di Tokamak. Berikutnya telah dilakukan studi pemecahan persamaan kinetika *space-time* secara lebih akurat pada semua jenjangnya dari point kinetik sampai *direct method*. Juga telah dilakukan studi untuk reaktor yang terapung termasuk dengan mempertimbangkan gerakan air laut. Juga telah dikembangkan lebih banyak program computer dengan fungsi untuk menunjang penelitian maupun untuk menunjang pendidikan nuklir, antara lain program netronik-thermal hidraulik terkopel untuk analisis BWR, program keselamatan berbasis model hot spot yang dapat diterapkan pada banyak tipe reaktor, model keselamatan kuasistatik beserta programnya, program modifikasi kode computer SLAROM untuk bagian collapsing grup konstannya yang semula memakai multigrup difusi 1 dimensi menjadi 2 dimensi multigrup difusi R-Z.

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Zaki Su'ud, yang lahir di Wonosobo pada 12 Desember 1962, merupakan anak kedua dari tiga bersaudara. Ia menikah dengan Astining Wahjoeniarty pada 1991 dan dikaruniai empat anak: Nabila, Burhan, Muhammad, dan Ibrahim. Pendidikan sekolah dasar ditempuh di SDN 3 Wonosobo, sekolah menengah di SMPN 1 Wonosobo dan sekolah lanjutan atas di SMAN I Wonosobo. Selanjutnya, ia

melanjutkan pendidikan tinggi di jurusan Fisika ITB dengan bidang spesialisasi fisika instrumentasi khususnya terkait nuklir. Pada tugas akhir S1, ia membuat sebuah komputer papan tunggal dengan sekitar 10 LSI yang digunakan untuk mengontrol spektrometer Mossbauer. Tugas akhir S1 dilakukan di bawah bimbingan Dr. Sutrisno (almarhum). Pada tahun 1987, ia diterima sebagai staf pengajar di departemen Fisika FMIPA ITB.

Selanjutnya pada 1989, ia meneruskan studi ke Tokyo Institute of Technology di department of Nuclear Engineering, Graduate School of Science and Engineering. Setelah menyelesaikan program bahasa dan *research student*, program master diselesaikan dalam 2 tahun, dan tahun 1992 mulai masuk program doktor di tempat yang sama. Program doktor diselesaikan dalam 3 tahun (1992–1995). Penelitian program master berfokus pada pengembangan kode komputer analisis difusi dan *burnup* 2 dimensi R-Z yang digunakan untuk menganalisa reaktor LMFBR modular yang dapat dioperasikan sampai 40 tahun tanpa mengisi ulang bahan bakar untuk LMFBR berpendingin sodium, Pb dan Pb-Bi masing-masing.

Untuk penelitian program doktor, fokusnya adalah merancang PLTN modular berbasis LMFBR dengan pendingin Pb/Pb-Bi cair yang dapat beroperasi sampai 10 tahun tanpa memerlukan pengisian dan pengaturan ulang bahan bakar selama periode tersebut. Selanjutnya dikembangkan program analisa kecelakaan ULOF, UTOP dan ULOHS dengan program fortran yang merupakan gabungan analisa kinetika ruang waktu dan analisa transien thermal hidraulik. Pada tahap selanjutnya dilakukan analisa kecelakaan pemblokan lokal dengan program analisa kecelakaan 3 dimensi R-T-Z yang ia kembangkan. Hasil-hasil penelitian S2 dan S3 dipublikasikan dalam 5 jurnal internasional, 4 buku/ prosiding serta lebih dari 10 seminar Gakkai bidang nuklir.

Sekembalinya dari Jepang, ia mengembangkan penelitian dalam 2 bidang yaitu analisis dan desain PLTN

generasi lanjut serta dalam bidang instrumentasi. Dalam bidang analisis dan desain PLTN generasi lanjut dilakukan pengembangan lebih lanjut dari program difusi dan *burnup*, serta program analisis kecelakaan yang ada dengan sejumlah pengembangan model dan fitur. Selain itu, mulai dilakukan studi desain PLTN berumur panjang tanpa pengisian ulang bahan bakar dengan basis PLTN PWR, BWR, HTGR, dan GCFR. Program analisis gabungan netronik dan thermal hidraulik untuk analisis BWR dikembangkan dengan bahasa fortran maupun delphi. Selain itu, sejumlah penelitian agak teoritik mulai dilakukan misalnya dengan melakukan analisis perhitungan cross-section dengan model RGM-GCM, HArtree FOCK beserta variasinya, perhitungan grup konstan dengan collision probability, dll.

Pada tahun 2005, ia mengembangkan penelitian *breed burn* reaktor dengan melakukan riset selama satu bulan di lab Prof. Sekimoto yang secara intensif mengembangkan reaktor jenis CANDLE. Dari penelitian inilah dihasilkan ide dan program untuk perhitungan skem *burnup* Modified CANDLE dengan menerapkan pembagian region dalam teras reaktornya. Penelitian tentang fusi juga mulai dilakukan dengan fokus pada perhitungan keseimbangan energi dan optimasi bahan untuk *blanket* dan *first wall* untuk reaktor tokamak. Berikutnya penelitian tentang korosi dan reaktor terapung juga dikembangkan. Untuk penelitian tentang korosi Pb-Bi cair setelah melalui 2 penelitian doktoral berhasil dicapai pembuktian teoritis/komputasional pertama di dunia bahwa korosi Pb-Bi dapat ditekan dengan optimasi kadar oksigen dalam bahan pendingin yang tepat. Penelitian MCANDLE juga berhasil menghasilkan desain yang dapat beroperasi dengan burnup minimal sekitar 18% (sesuai batas limit teoritis yang dikemukakan oleh Prof. Ehud Greenspan dari Univ. California Berkeley). Selanjutnya dengan memakai input bahan bakar berupa bahan bakar bekas PWR maka dapat dicapai reaktor MCANDLE yang dapat beroperasi dengan burnup keluaran sekitar 16%

sehingga dapat menggunakan bahan material generasi lanjut untuk reaktor cepat.

Dalam 10 tahun terakhir sejalan dengan kemajuan komputer penelitian dengan program Monte Carlo dan analisis 3 dimensi yang lebih akurat mulai banyak digunakan di dunia. Sejalan dengan itu ia mengembangkan sejumlah komputer klaster untuk melakukan komputasi paralel guna menunjang penelitian analisis reaktor nuklir yang lebih canggih.

Sejak 2007 mulai dilaksanakan konferensi internasional ICANSE yang ia inisiasi beserta sejumlah kolega. Sampai 2018 ada konferensi ICANSE dengan prosiding yang dipublikasikan di *AIP conf proceeding* dan *IOP JOurnal of Physics conference proceedings.*

Ia telah menghasilkan 225 paper yang terbit di SCOPUS dan lebih dari 100 paper lain di jurnal nasional, prosiding nasional, dll. Sejumlah paten sedang diusulkan terkait desain reaktor MCANDLE generasi terbaru dan sejumlah program komputer baru yang dihasilkan. Sejauh ini ia telah meluluskan 160 mahasiswa meliputi 25 mahasiswa S3, 60 mahasiswa S2 dan 75 mahasiswa S1.

Dalam penelitiannya, ia banyak melakukan kerja sama, antara lain dengan BATAN (BRIN-ORTN), BAPETEN, UGM, UNSRI, UNAND, Tokyo Tech, Tokyo City University, Osaka Univ., Gazi Univ., dll. Kerjasama dengan BATAN antara lain dikembangkan melalui forum *IFAR (Indonesian Forum of Advanced Reactor)*. Adapun kerja sama dengan BAPETEN antara lain terkait pengembangan regulasi untuk PLTN.

Pengalaman Mengajar

Basic Physics, Electronics, Advanced Instrumentation, Reactor Physics, Advanced Reactor Physics, Nuclear Physics, Computational Nuclear Physics, System programming for instrumentation, Quantum Physics, Quantum Mechanics.

Pengalaman Jabatan

Asisten 1986–1996

Dosen 1996–1999

Associate Prof. 1999–2010

Professor sejak Juli 2010

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Pengalaman Riset (5 tahun terakhir)

No.	Tahun	Judul Penelitian	Pendanaan	
			Sumber	**Jml (Juta Rp)**
1.	2023	Pengembangan Program Analisis Terintegrasi untuk GCFR	PPMI FMIPA (PI)	50
2.	2023	Studi Desain dan Analisis PLTN Modular berbasis Modified CANDLE dengan menggunakan sisa bahan bakar PWR sebagai masukan siklus bahan bakar	Riset Unggulan ITB (PI)	150
3.	2022	Desain Aspek Keselamatan untuk PLTN Modular Suhu Tinggi berbasis GCFR dengan daya 50-300 MWe	Penelitian Dasar Unggulan PT (PI)	104,5
4.	2022	Optimasi Aspek Netronik dan Analisa Thermal Hydraulik PLTN Sangat Kecil (Nano Reactor) untuk Penggunaan di Indonesia)	Riset Unggulan ITB (PI) (PI)	150

No.	Tahun	Judul Penelitian	Pendanaan	
			Sumber	Jml (Juta Rp)
5.	2021	Studi Desain dan Analisis PLTN Modular Berpendin-gin Gas Helium berspek-trum netron cepat berdaya 75- 200MWe dengan ura-nium alam sebagai input siklus bahan bakarnya	Penelitian Unggulan PT (PI)	123,77
6	2021	STUDI DESAIN DAN ANAL-ISIS PLTN SANGAT KECIL (NANO REACTOR) UNTUK PENGGUNAAN DI INDO-NESIA	Riset Unggu-lan ITB (PI)	150
7	2020	Studi Desain PLTN modular 200-400 MWt berpendingin Pb/Pb-Bi dengan tempera-tur keluaran tinggi	Penelitian Unggulan PT (PI)	112,928
8	2020	Pengembangan dan Opti-masi program analisa ke-celakaan ULOF untuk PLTN Generasi IV jenis Pb/Pb- Bi Cooled Fast Reactors pada komputer klaster Tahap II : Optimasi di komputer klaster dan pengembangan antara muka dengan kod ekomputer SLAROM	Riset KK A ITB (PI)	150

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Liem Peng Hong lahir bulan Maret 1962 dari pasangan Liem Khiem Tjong dan A. T. Soemarto, dibesarkan di Semarang sebagai anak ketiga dari empat bersaudara. Setelah lulus SMA, pada tahun 1981 ia meninggalkan Semarang menuju Yogyakarta untuk menempuh pendidikan S-1 di Jurusan Teknik Nuklir (TN), Fakultas Teknik, Universitas Gadjah Mada (UGM). Hobi semenjak SMP dan SMA adalah elektronika, bahasa Inggris, dan bahasa Jerman.

Program S-1 TN ini baru dibuka tahun 1981, sehingga ia menjadi angkatan pertama dan menjadi lulusan tercepat (pertama) sekaligus *cum-laude* pada ujian pendadaran S-1 Desember 1985. Di antara dua program studi TN saat itu, ia memilih program studi Teknologi Reaktor (yang lain adalah Teknologi Nuklir) yang memberi dampak besar pada arah karirnya mendatang. Selama kuliah S-1, ia juga banyak mengambil mata kuliah pilihan di Teknik Elektro, sebagian sebagai penyaluran hobi. Tugas akhirnya adalah desain dan pembuatan alat ukur reaktivitas digital untuk Reaktor Kartini BATAN Yogyakarta (reaktor riset dan pelatihan jenis TRIGA). Saat itu, Indonesia (BATAN) baru memiliki 2 reaktor riset, yakni Reaktor Kartini dan Reaktor Bandung (juga jenis TRIGA), dan alat ukur reaktivitas kedua reaktor yang dipakai masih bersifat analog serta dibeli dari luar negeri. Rekayasa alat ukur reaktivitas digital ini merupakan yang pertama di Indonesia, dan baginya menjadi paduan antara hasil pendidikan formal TN dan hobi elektronikanya. Masa pendidikan S1 TN inilah yang dirasakan paling menumbuhkan kecintaan pada ilmu fisika reaktor, karakter panggilan sebagai insinyur (membangun sesuatu & menyelesaikan masalah), serta disiplin, etik dan metode ilmiah.

Setelah selesai S-1 (1986) ia mendapat tawaran dari BATAN untuk menjadi peneliti dan tawaran dari UGM menjadi pengajar Jurusan Teknik Nuklir. ia memilih masuk ke BATAN, dan sementara sebagai calon pegawai negeri sipil, dititipkan di Pusdiklat BATAN Yogyakarta. Selama di Pusdiklat, ia membantu tugas pendidikan dan latihan PATN (Pendidikan Ahli Teknik Nuklir), melakukan penelitian dan pengembangan (litbang) dan pembuatan program analisis probabilitas pohon kegagalan reaktor nuklir. Saat itu, ia belum menyadari bahwa bidang ini akan menjadi sangat penting saat ini di Jepang terutama setelah kecelakaan pembangkit listrik tenaga nuklir (PLTN) Fukushima Dai-Ichi (2011). Pasca-kecelakaan ini, upaya peningkatan keselamatan PLTN Jepang bertumpu pada metodologi analisis resiko probabilitas.

Ia terpilih mendapat tugas belajar pasca sarjana bidang teknik nuklir di Tokyo Institute of Technology (TIT) Jepang mulai tahun 1987. Program pasca sarjana S-3 selesai tahun 1993 (*cum-laude,* dengan gelar *Doctor of Engineering*). Disertasi S-3 bertema litbang desain reaktor riset fluks tinggi dengan moderator grafit dan pendingin gas helium, yang mencakup aspek desain netronik, manajemen bahan bakar teras, termohidrolik, serta analisis dan simulasi kecelakaan reaktor. Bidang reaktor riset ini sangat dibutuhkan BATAN dengan dimulainya pembangunan dan pengoperasian reaktor riset (ketiga dan terbesar) *multi-purpose* G.A. Siwabessy di Kawasan Puspiptek Serpong era akhir 80-an. Selain bidang reaktor riset, selama di TIT ia juga melakukan litbang PLTN jenis *high-temperature gas-cooled reactor* (HTGR), yang pada akhir 80-an mulai dipertimbangkan sebagai reaktor masa depan dengan tingkat keselamatan melekat yang tinggi. Saat itu, ia belum tahu bahwa tipe reaktor ini di masa depan akan terpilih menjadi salah satu jenis reaktor Generasi IV, dan akan menjadi proyek besar litbang BATAN/BRIN yakni Reaktor Daya Eksperimental (RDE) tipe HTGR (2014).

Selesai pendidikan program S3, ia ditempatkan di Pusat Reaktor Serba Guna (PRSG) G.A. Siwabessy (RSG GAS) di Bidang Fisika Reaktor (BFR). Selain tugas rutin perhitungan dan eksperimen fisika reaktor, ia melakukan litbang pengembangan perangkat lunak fisika reaktor untuk RSG GAS (program BATAN-2DIFF, -3DIFF, BATAN-FUEL, MTR-DYN). Program-program tersebut sampai saat ini masih digunakan oleh BATAN/BRIN dalam operasi, manajemen bahan bakar serta analisis transien/kecelakaan RSG GAS, dan mampu menggantikan seluruh program-program yang disediakan oleh pemasok RSG GAS (Interatom, Jerman). Selain untuk reaktor riset, pengembangan perangkat lunak reaktor daya HTGR tipe *pebble-bed* reactor (program BATAN-MPASS, BATAN-Peu), dan reaktor daya jenis *pressurized water reactor* (PWR) (program NODAL3) juga dilakukan. Saat itu, reaktor daya HTGR dan PWR ini direncanakan akan dibangun masing-masing di Kepulauan Natuna (panas proses untuk *Enhance*

Oir Recovery) dan di Semanjung Muria (pembangkitan listrik). Program BATAN-MPASS kemudian dipakai oleh ia dan rekan-rekan peneliti dalam analisis dan desain RDE BATAN. Selama di PRSG, ia melakukan desain konversi teras oksida ke silisida RSG GAS dengan tujuan meningkatan umur teras dan pendayagunaan reaktor. Teras silisida yang dirancang berhasil direalisasi (awal tahun 2000-an) dan dioperasikan dengan selamat sampai saat ini (teras No. 108). Teras silisida ini lebih unggul, ekonomis, dan lebih mudah dioperasikan dibanding teras oksida awal rancangan pemasok Jerman. Selain itu, kerjasama dengan Pusat Elemen Bakar Nuklir (PEBN) dalam mempersiapkan jenis elemen bakar reaktor riset masa depan dengan muatan lebih tinggi juga dilakukan melalui desain plat bahan bakar mini. Eksperimen iradiasi plat bahan bakar mini di RSG GAS sudah berhasil dilakukan dengan selamat, dan sekarang sedang dilakukan evaluasi pasca iradiasi.

Sejak 1999 sampai saat ini (2024, genap 25 tahun) ia melanjutkan karir di satu perusahaan penyedia jasa industri nuklir Jepang (NAIS Co., Inc., lokasi Tokaimura) sambil menjadi *Visiting Professor* di Tokyo Insitute of Technology (TIT), Tokyo City University (TCU), dan *Lecturer* di Sophia University. Pengguna jasa NAIS mencakup institusi litbang nuklir pemerintah (JAEA, IEA dll.), badan regulasi nuklir (NRA, NMCC), perusahaan pemasok reaktor (Mitsubishi, Hitachi-GE dll.), produsen elemen bakar nuklir (NFI), perusahaan listrik swasta dan grup (Shikoku Electric Power Company, TEPCO, TEPSYS dll.), universitas (Tsukuba University, Tokyo University, TIT, TCU dll.) dll. Kontrak-kontrak komersial meliputi bidang energi nuklir secara umum, analisis dan desain netronik serta termohidrolik berbagai macam perangkat kritis, reaktor riset, reaktor daya, akselerator, analisis resiko probabilistik, dekomissioning fasilitas nuklir, penyimpanan limbah lestari, kedokteran nuklir dan terapi

BNCT, perisai radiasi fasilitas nuklir termasuk reaktor fusi ITER, evaluasi data nuklir, pengembangan perangkat lunak fisika reaktor, dan jasa layanan lainnya. Dalam perjalanan karir di Jepang, ia mengalami sendiri dua kecelakaan nuklir utama, yakni kecelakaan kekritisan JCO Tokaimura (5 km dari rumah, September 1999) dan kecelakaan parah PLTN Fukushima Dai-Ichi (125 km dari rumah, Maret 2011), yang memberikan dampak khusus pada kegiatan litbang dan isi kontrak komersial yang diterima yang tidak bisa dijumpai di negara lain. Di universitas, selain litbang, ia juga melakukan bimbingan mahasiswa/i Indonesia, yang setelah lulus sekarang sudah tersebar di BATAN/BRIN, BAPETEN, IAEA, perguruan tinggi dan perusahaan swasta.

Kerja sama litbang dan pengembangan sumber daya manusia dengan institusi BATAN/BRIN (PRSG, PTKRN, PEBN dll.) lebih meningkat setelah ia berada di Jepang, termasuk pembentukan dan peningkatan jaringan hubungan antara lembaga litbang, regulasi nuklir dan universitas Jepang-Indonesia. Fokus kerma litbang salah satunya adalah pendayagunaan RSG GAS untuk produksi radiofarmaka Tc-99m/Mo-99 dengan menggunakan Mo alam, *Neutron Transmutation Doping (silicon wafer)*, eksperimen fisika reaktor baru & partisipasi CRP IAEA dengan memakai RSG GAS; partisipasi desain dan analisis proyek RDE, IAEA *expert mission* ke Reaktor Triga Bandung, teknologi terapi BNCT, dll. Beberapa kunjungan dan kerja singkat atas undangan PRSG (RSG GAS) dilakukan dalam mencari solusi problem keselamatan dan perijinan operasi RSG GAS. Pada acara ulang tahun ke-34 RSG G. A. Siwabessy, ia menerima penghargaan tertinggi dari PRSG atas dedikasi dan kontribusinya selama tiga dekade.

Repositori

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Pendidikan

Apr 1990 – Mar 1993	Tokyo Institute of Technology Doctor of Engineering, Nuclear Engineering Tokyo, Japan
Apr 1988 – Mar 1990	Tokyo Institute of Technology Master of Engineering, Nuclear Engineering Tokyo, Japan
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Jul 1981 – Dec 1985	Gadjah Mada University Engineer, Nuclear Engineering Yogyakarta, Indonesia

Tesis

Liem Peng Hong: *Design Study on the Graphite Moderated Helium-Cooled High Flux Reactor (in Japanese)*. 03/1993, Degree: Doctor of Engineering, Supervisor: Prof. Hiroshi Sekimoto

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Oct 2009 – Mar 2011	Lecturer Tokyo Institute of Technology, Research Laboratory for Nuclear Reactors Tokyo, Japan
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Sep 1995 – Feb 1996	Invited Researcher Japan Atomic Energy Research Institute, Department of Research Reactor Tokaimura, Japan
Nov 1986 – Dec 1998	Senior Researcher Badan Tenaga Nuklir Nasional, Jakarta, Indonesia

Professional Society

1) Atomic Energy Society of Japan
2) Atomic Energy Society of Indonesia
3) Member of Expert Group on Burnup Credit, Working Party on Nuclear Criticality Safety (WPNCS), Nuclear Energy Agency (NEA), Organization for Economic Co-operation and Development (OECD)
4) Member of Expert Group on Criticality Excursion Analysis, WPNCS, NEA, OECD

Publikasi

Buku

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3) 原子力年鑑2022、第7章「各国・地域の原子力動向」アジア・インドネシア、日刊工業新聞社(2021)
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7) Liem Peng Hong, "最先端研究基盤JMTR及び関連施設を用いた研修講座のための核計算用テキスト," 原子力研究開発機構・大洗研究開発センター・照射試験センター（平成23年3月）。

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Paten

Judul Paten	: Perangkat Transmutasi Nuklir
Nomor	: 2020-046979
Diajukan1	: 17 Maret 2020
Pemegang Paten	: 4 orang (di antaranya Liem Peng Hong memiliki kontribusi 25 %)
Isi Paten	: Rancang bangun perangkat untuk transmutasi nuklir limbah produk fisi waktu paruh panjang di reaktor spektrum netron cepat

Penjelasan rinci dapat dibaca pada publikasi ilmiah paten ini :

Yoshihisa Tahara, Peng Hong Liem, Naoyuki Takaki and Satoshi Chiba, "Design of Cesium target assembly with YH2 moderator and Gd thermal neutron shielding to produce 135Cs for LLFP transmutation study using the experimental fast reactor Joyo," Annals of Nuclear Energy 166 (2022) 108830.

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3. Liem Peng Hong, "Different Types of Nuclear Reactors (General Lecture)," Yogyakarta State University, Yogyakarta, Indonesia (May 18, 2017).
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2. Soma Nakamura, Naoyuki Takaki, Liem Peng Hong, "Preliminary Analysis of "Nuclear Alchemy" Demonstration Experiment to Generate Gold from Mercury – (2) Optimization of Mercury Target Specification –," Annual Meeting of the Atomic Energy Society of Japan (September 11-13, 2019), Toyama University, Toyama City, Japan.
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1 BATAN: Indonesian National Nuclear Energy Agency

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Academic Society Activities

1. Atomic Energy Society of Japan, Expert Committee on Thorium Energy System (member) (2020-present).
2. International Scientific Committee (member): ASTECHNOVA 2017 International Energy Conference, Gadjah Mada University, Jogjakarta (2017).
3. International Scientific Committee (member): ASTECHNOVA 2016 International Energy Conference, Gadjah Mada University, Jogjakarta (2016).
4. International Scientific Committee (member): ASTECHNOVA 2015 International Energy Conference, Gadjah Mada University, Jogjakarta (2015).
5. International Scientific Committee (member): The 3rd Applied Science for Technology Innovation (ASTECHNOVA 2014) International Energy Conference, Gadjah Mada University (2014).

6. International Advisory Committee (member): The 4th International Conference on Advances in Nuclear Science and Engineering (ICANSE 2013), Bandung (2013).

7. Organizing & Technical Program Committees (member): First COE-INES International Symposium (INES-1), Tokyo Institute of Technology (2004)

8. 21世紀COEプログラム拠点形成計画「世界の持続的発展を支える革新的原子力」（COE-INES）事業推進（研究、教育拠点形成、インドネシア等国際拠点形成活動）、東京工業大学、原子炉工学研究所、（2004年4月～2007年9月）。

9. Expert Group on Criticality Excursion Analysis (member), Working Party on Nuclear Criticality Safety (WPNCS), Nuclear Energy Agency (NEA), Organization for Economic Co-operation and Development (OECD); Publication: Y. Miyoshi, Y. Yamane, K. Okubo, L. Reverdy, P. Grivot, H. Konishi, S. Mitake, Peng Hong Liem, "Inter-code Comparison Exercise for Criticality Excursion Analysis; Phase I: Pulse Mode Experiments with Uranyl Nitrate Solution in the TRACY and SILENE Facilities", OECD/NEA (2009)

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PERAN LITBANG FISIKA REAKTOR DALAM PENYELESAIAN PROBLEM-PROBLEM REAKTOR SERBA GUNA G. A. SIWABESSY

Liem Peng Hong
Nippon Advanced Information Service (NAIS)
Tokyo City University (TCU)

5 Des. 2024

Memorial Lecture G. A. Siwabessy 2024, BRIN, Jakarta, Indonesia

Ucapan Terimakasih dan Selamat

- Keluarga Besar G. A. Siwabessy
- Badan Riset dan Inovasi Nasional (BRIN /BATAN)
  - Pusat Reaktor Serba Guna G. A. Siwabessy (PRSG, Serpong)
  - Pusat Teknologi dan Keselamatan Reaktor Nuklir (PTKRN, Serpong)
  - Pendidikan Ahli Teknik Nuklir (PATN, Pusdiklat, Yogyakarta)
  - Reaktor R. A. Kartini (Yogyakarta)
- Institusi Pendidikan
  - Jurusan Teknik Nuklir, Fakultas Teknik, Universitas Gadjah Mada (UGM)
  - Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology (Tokyotech)
- Institusi Karir di Jepang
  - NAIS Co. Inc.
  - Japan Atomic Energy Agency (JAEA)
  - Japan Nuclear Regulatory Authority (NRA)
  - Tokyo Institute of Technology (Titech)
  - Tokyo City University (TCU)
  - Sophia University
- Himpunan Keilmuan dan Profesi
  - Japan Atomic Energy Society (AESJ)
  - OECD/NEA/NSC/Working Party Nuclear Criticality Safety (WPNCS)
    - Expert Group on Burnup Credit
    - Expert Group on Criticality Excursion Analysis
  - Himpunan Masyarakat Nuklir Indonesia (HIMNI)

Isi

1. Ilmu Fisika Reaktor Kontribusi BRIN/BATAN

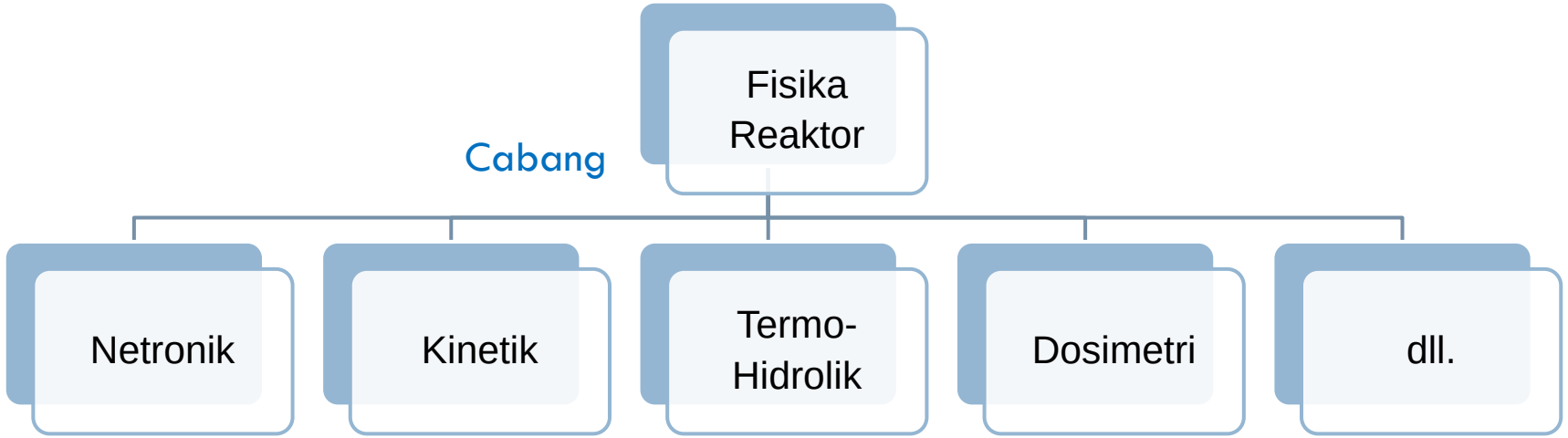
2. Fisika reaktor dalam penyelesaian tantangan dan problem RSG G. A. Siwabessy

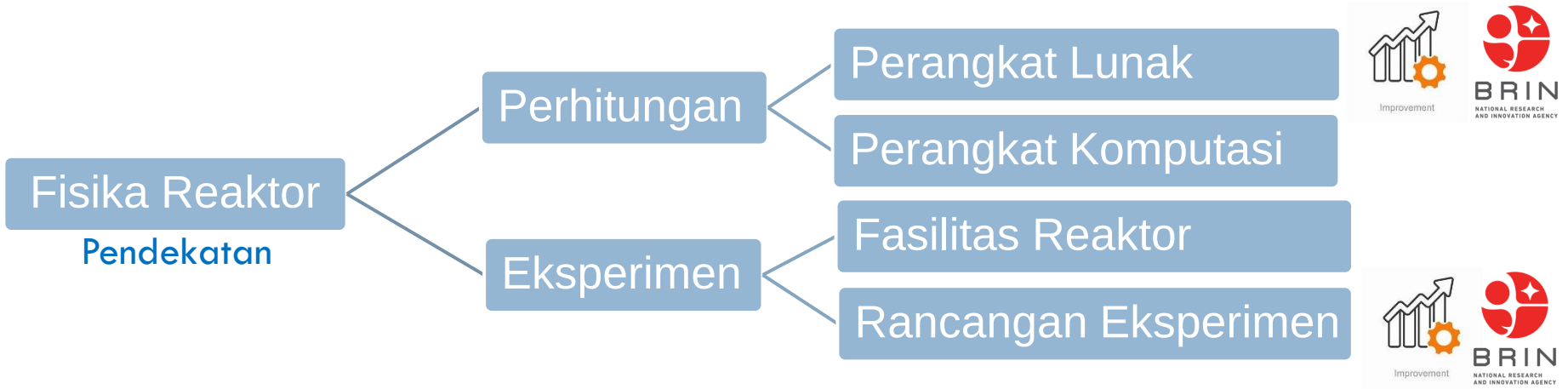
3. Masukan bagi pengembangan SDM nuklir

4. Tema litbang *frontier* bagi SDM nuklir generasi mendatang

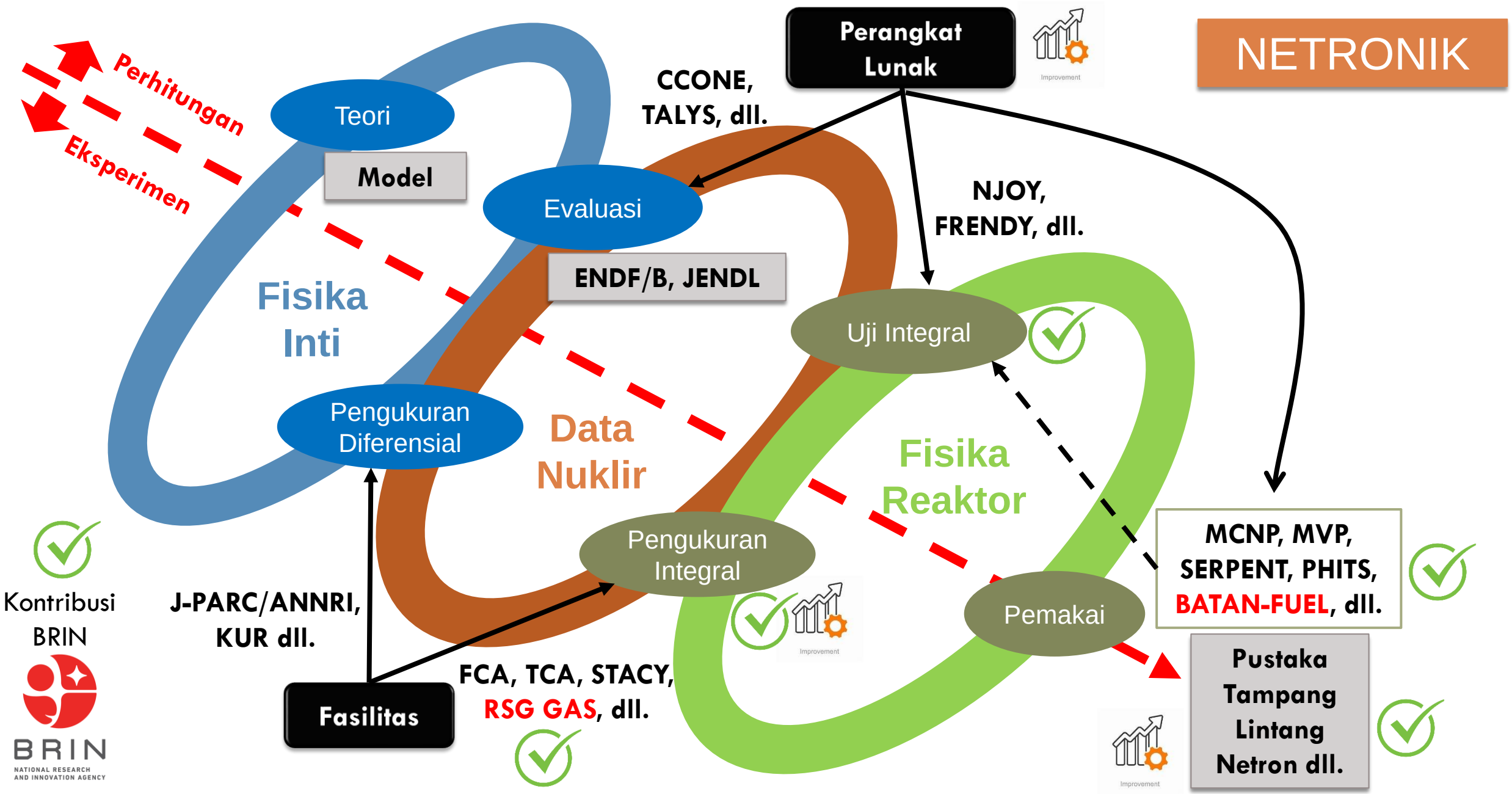
- Pemaparan ilmiah rinci mohon dilihat di Repositori KTI (ResearchGate):
  - https://www.researchgate.net/profile/Liem-Hong/research
  - Selama 35 tahun dari 56 publikasi fisika reaktor di jurnal ilmiah internasional 17 publikasi (30%) menyangkut Reaktor Serba Guna G. A. Siwabessy.

Fisika Reaktor (Cabang ilmu fisika yang membahas tentang fenomena yang terjadi di dalam reaktor nuklir)





Perlu Peningkatan Khusus


NETRONIK
Perangkat Lunak
Perhitungan
Eksperimen
Teori
Model
Evaluasi
CCONE, TALYS, dll.
ENDF/B, JENDL
NJOY, FRENDY, dll.
Fisika Inti
Data Nuklir
Fisika Reaktor
Uji Integral
Pengukuran Diferensial
Pengukuran Integral
Pemakai
MCNP, MVP, SERPENT, PHITS, BATAN-FUEL, dll.
Pustaka Tampang Lintang Netron dll.
Kontribusi BRIN
J-PARC/ANNRI, KUR dll.
Fasilitas
FCA, TCA, STACY, RSG GAS, dll.
BRIN
NATIONAL RESEARCH AND INNOVATION AGENCY

Peran Fisika Reaktor (terkait RSG G. A. Siwabessy)

Kontribusi dalam **pengembangan Iptek**

- Umpan balik tes integral ke data nuklir JENDL-5, ENDF/B-VIII.0 (Analisis kekritisan, S/U, similaritas RSG GAS dll.)
- Umpan balik hasil eksperimen integral ke data nuklir lewat publikasi ilmiah tingkat internasional, CRP IAEA dll. (teras pertama, teras setimbang silisida RSG GAS)
- Pengembangan secara mandiri metode, teknik inovatif (interaksi batang kendali RSG GAS), dan perangkat lunak untuk operasi rutin RSG GAS (BATAN-FUEL), analisis transien dan keselamatan RSG GAS (MTR-DYN), ekstrapolasi kapabilitas untuk PLTN air (NODAL3) dan HTGR (BATAN-MPASS dll.)
- Pengembangan desain eksperimen di RSG GAS (pengukuran tingkat bakar tak-merusak dalam kondisi sub-kritis dll.)

Kontribusi dalam **pemecahan problem**

- Interaksi dengan tuntutan badan regulasi (verifikasi & validasi tingkat bakar maksimum, reaktivitas lebih teras & batang kendali, margin keselamatan, ketidak-setimbangan distribusi daya teras dll.)
- Konversi teras oksida ke silisida (dan muatan tinggi) setimbang dengan pola inovatif pemuatan tetap 5/1 (pendayagunaan, ekonomi, keselamatan)
- Peningkatan dan revitalisasi fasilitas pelayanan RSG GAS
  - Kerma BATAN-KAKEN-NAIS: Produksi radiofarmaka Mo-99/Tc-99m dengan Mo alam
  - Kerma BATAN-TCU: Neutron Transmutation Doping (Silicon Wafer)
  - Iradiasi elemen bakar silisida muatan tinggi (plat mini)
- Problem terkini RSG GAS (bahan bakar, penuaan)

Masukan bagi pengembangan SDM nuklir

- 1. Perencanaan Strategis & Dukungan Anggaran
  - Strategi Jangka Panjang (Konsisten)
  - Industri Nuklir (Kompetensi)
  - Kebutuhan Lapangan Kerja (Jenis & Jumlah), dll.
- 2. Pendidikan dan Latihan, Pembinaan Karakter
  - Pemula s/d Profesional (Inovatif/Kreatif, Kompetitif, Ulet, Disiplin, Budaya Ilmiah dan Etika Tinggi)
  - Menjaring SDM (pemula) bertalenta secara nasional
  - Kurikulum Khusus (diperbarui terus), Sertifikasi
  - Lintas Institusi (Univ/Lembaga Litbang-Industri-Pemerintah) (産学官), dll.
- 3. Manajemen Pengetahuan, Keahlian & Ketrampilan
  - Sistem Dokumentasi, Basis Data yang mapan
  - Menjaga dan meneruskan keahlian & ketrampilan dari senior (termasuk pensiunan) ke junior, dll.
- 4. Kolaborasi Internasional
  - Fasilitas Eksperimen (mahal) & Resources
  - Pasca Sarjana, Pasca Doktoral
  - Best Practices, dll.
- 5. Penggunaan Teknologi Informasi
  - Open Source, E-Learning, Online Tools, dll.

Urutan prioritas berdasarkan situasi nasional

1. Fisika Reaktor
2. Data Nuklir
3. Fisika Inti

Tema Litbang *Frontier* untuk Pembinaan SDM Nuklir Generasi Mendatang

- Fisika Reaktor
  - Desain Reaktor Maju (SMR, HTGR, FR, MSR)
  - Multiphysics (Netronik-Kinetik-Thermohidrolik)
  - Metoda Komputasi Maju (Virtual Reactor)
  - Kuantisasi Ketidakpastian (U/Q) dan Pendekatan Probabilistik
  - Aplikasi Machine Learning dan AI
  - Metode Baru untuk Eksperimen Kekritisan dan Sub-Kritis
  - dll.
- Data Nuklir
  - Thermal Scattering Law
  - Muon Interaction Data
  - Data Nuklir untuk Back-End, Medis, Nuclear Security
  - Aplikasi Machine Learning dan AI
  - dll.
- Fisika Inti
  - Aplikasi medis: pengembangan teknik diagonistik dan terapi nuklir yang baru
  - Pengembangan teori 3-body nuclear force
  - dll.

Terimakasih

- NAIS Co., Inc: https://www.nais.ne.jp/
- Tokyo City University: https://www.tcu.ac.jp/

Tayangan tambahan

Collaborations with BRIN/BATAN (1)

FGD Reaktor Riset Indonesia (BATAN PSTA Mei 2021)

- BATAN-KAKEN-NAIS Project (2019 ~ present)
  - Production of Mo-99/Tc-99m from natural Mo
  - Irradiation targets and capsules preparation finished
  - Irradiation plan in RSG GAS
- RSG GAS Silicide Fuel Development (Post Irradiation Experiment, PIE)
  - Non-destructive PIE finished (2.96 g/cm^3)
  - Destructive PIE finished (2.96 g/cm^3)
  - Destructive PIE and Evaluation (Miniplate, 4.8 g/cm^3) is undergoing

Collaboration with BRIN/BATAN (2)

BATAN-KAKEN-NAIS Project (BATAN, Serpong, August 2019)

Nat-Mo Pellet & NAC Aluminium tubes, Analysis results, etc. (Japan→BATAN)

Collaborations with BRIN/BATAN (3)

BATAN-KAKEN-NAIS Project (Mito, Japan, December 2019)

Collaborations with BRIN/BATAN (4)

BATAN-Tokyo City University Project (2019-2020)

- Si wafer NTD Experiment
- Radial homogeneity
- Irradiation damage etc.

•Half numbers of wafers were sent to TCU, the other half remained in BATAN for domestic research

Collaborations with BRIN/BATAN (5)

F: Finished
C: Undergoing

- RSG GAS Utilization
  - Regulatory compliance
    - Maximum burnup (F)
    - Control rod interference (F)
    - Sub-criticality margin (F)
    - Unbalance power (F), etc.
  - Reactor physics experiments
    - Under subcritical cond. (F)
    - Under critical cond. (C)
    - Radial (F) and axial (C) burnup distributions (equilibrium Si core)
  - Reevaluation of measured data during commissioning using state-of-the-art methods and codes
    - Assessment on calculation errors (methods, codes, libraries) (F, C)
    - Future improvement on the in-core fuel management (methods, codes, libraries) (C)

Suggestions & Discussion Items

- Evaluation of the existing facilities which are not yet utilized
  - PRTF, etc.
- Evaluation of the existing facilities/components which are threatened by aging problems
  - Be element/reflector
  - I & C, Reactor Protection System (RPS), etc.
- Knowledge, know-how conservation and transfer to next/young generation
- Synergy amongst BATAN internal units
- Collaboration with external institutions (domestic and international)

Problem terkini RSG GAS(1)

Pertemuan dengan BRIN/ORTN April 2024

Peran/Aplikasi Fisika Reaktor dalam penyelesaian masalah

- Jangka pendek
  - Ketersediaan elemen bakar (baru) untuk operasi rutin RSG GAS.
  - Pemanfaatan elemen bakar yang ada (lama) untuk memenuhi tuntutan pelayanan iradiasi dan kerjasama dengan institusi lain.
  - dll.
- Jangka panjang
  - Peremajaan instrumen ukur dan kendali, keselamatan reaktor.
  - dll.

Problem terkini RSG GAS(2)

Pertemuan dengan BRIN/ORTN
5-6 Sept. 2024

- Problem operasi RSG GAS
  - Aplikasi fisika reaktor dalam strategi penghematan pemakaian elemen bakar yang tersisa untuk operasi RSG GAS.
  - Fisika reaktor (termo-hidrolika) dalam menjaga akurasi kalibrasi daya reaktor RSG GAS dalam keterbatasan usia dan jumlah instrumen.
  - Penentuan penyebab kenaikan paparan radiasi udara di anjung operasi.
- Produksi radiofarmaka
  - Inovasi fisika reaktor yang dibutuhkan dalam optimasi produksi Mo-99/Tc-99m.

Panduan dan
Profil Penghargaan

Siwabessy Award dan G.A. Siwabessy Memorial Lecture Tahun 2024

BRIN Publishing
The Legacy of Knowledge

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