

ECONOMICS OF FAST REACTOR-AN INDIAN PERSPECTIVE



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INTRODUCTION

- FOR THE LARGE COUNTRY LIKE INDIA , LONG TERM ENERGY SECURITY, MAINLY BASED ON INDIGENOUS RESOURCES IS AN IMPORTANT AND INEVITABLE NEED ARISING FROM ECONOMIC, GLOBAL ENVIRONMENT AND STRATEGIC CONSIDERATION
- THESE CONSIDERATIONS WILL DICTATE OPTIMUM COMPOSITION OF INDIA'S ENERGY MIX

INDIAN SCENARIO

- INDIAN SCENARIO IN TERMS OF NUCLEAR FUEL RESERVE AS WELL AS ITS NUCLEAR POWER PROGRAMME IS UNIQUE
- INDIA HAS ONLY MODERATE RESERVES OF URANIUM BUT IT IS ENDOWED WITH LARGE RESERVES OF THORIUM
- INDIA'S INDIGENOUS NUCLEAR PROGRAMME IS, THEREFORE , BASED ON USING LARGE RESOURCES BASE OF THORIUM THROUGH THREE STAGE NUCLEAR POWER PROGRAMME
- THE THREE STAGE NUCLEAR PROGRAMME BASED ON CLOSED NUCLEAR FUEL CYCLE WAS OUTLINED AS EARLY AS 1954.

THREE STAGE PROGRAMME

THE THREE STAGE NUCLEAR PROGRAMME:

- Stage I : PRESSURISED HEAVY WATER REACTORS (PHWRs) USING NATURAL URANIUM FUEL.
- Stage II : FAST BREEDER REACTORS USING PLUTONIUM RECOVERED FROM SPENT FUEL DISCHARGED BY PHWRs.
- Stage III : THORIUM BASED REACTORS

THREE STAGE PROGRAMME

- THE THREE STAGES OF PROGRAMME HAVE IMPORTANT FUEL CYCLE LINKAGES AND HAVE TO BE GONE THROUGH SEQUENTIALLY.
- HENCE THE FBR IS A BRIDGE TO THORIUM UTILISATION AND TO MULTIPLY INSTALLED NUCLEAR POWER CAPACITY SEVERAL FOLD FROM THE LIMIT OF 10-12 GWe (PHWR) IMPOSED BY DOMESTIC URANIUM AVAILABILITY

FIRST STAGE AT A GLANCE

- FIRST STAGE OF NUCLEAR POWER PROGRAMME IS IN COMMERCIAL DOMAIN.
- NPCIL IS IMPLEMENTING FIRST STAGE
- NPCIL OPERATES 20 REACTORS (18 PHWRs AND 2 BWRs) AND 6 REACTORS UNDER CONSTRUCTION
- THE OVERALL AVAILABILITY FACTOR (2012-13 TILL JAN) OF THE FULL FLEET IS 91% AND CAPACITY FACTOR 80%

THE SECOND STAGE

- FBTR HERALDED INDIA'S ENTRY TO SECOND STAGE OF NUCLEAR POWER PROGRAMME
- AIM IS NOT ONLY A TEST REACTOR FOR DEVELOPMENT OF ADVANCED FUELS AND STRUCTURAL MATERIALS, BUT ALSO A POWER DEMONSTRATOR REACTOR.
- 27 YEARS OF OPERATION OF FBTR WITH NO MAJOR PROBLEMS HAS PROVIDED CONFIDENCE TO PURSUE THE FBR PROGRAMME

THE SECOND STAGE

- FBTR AS WELL AS WORLDWIDE FBR OPERATIONAL EXPERIENCE, 30 YEARS OF FOCUSED R&D PROGRAMME INVOLVING EXTENSIVE TESTING AND VALIDATION, MATERIAL AND MANUFACTURING TECHNOLOGY DEVELOPMENT AND DEMONSTRATION, PEER REVIEWS AND SYNERGISM AMONG DAE UNITS, R&D INSTITUTIONS AND INDUSTRIES, HAVE PROVIDED THE NECESSARY CONFIDENCE TO LAUNCH PFBR 500 MWe

PFBR-BHAVINI

- BHARATIYA NABHIKIYA VIDYUT NIGAM LIMITED (BHAVINI) WAS INCORPORATED ON OCT 2003 FOR IMPLEMENTING PFBR PROJECT.
- PFBR IS THE FORERUNNER FOR THE SERIES OF FAST REACTORS THAT ARE PLANNED TO BE DEPLOYED
- IT SYMBOLISES COMMENCEMENT OF SECOND STAGE OF NUCLEAR POWER PROGRAMME
- PRESENTLY PFBR IS UNDER ADVANCED STAGE OF CONSTRUCTION AT KALPAKKAM
- DEMONSTRATE TECHNO ECONOMIC VIABILITY OF THE SECOND PHASE OF NUCLEAR POWER PROGRAMME OF THE COUNTRY

FAST BREEDER REACTORS

- FAST BREEDER REACTORS ARE MORE IMPORTANT TO INDIA THAN TO OTHER COUNTRIES WHICH HAVE CAPABILITIES IN NUCLEAR POWER TECHNOLOGY
- THIS IS BECAUSE OF NUCLEAR RESOURCE PROFILE WE HAVE IN INDIA
- TO DATE FBRs HAVE BEEN BUILT AND OPERATED WORLDWIDE, RANGING FROM RESEARCH REACTORS OF SOME TENS OF MW THERMAL OUTPUT TO 1200 MWe SPX1
- THE FAST REACTOR HAS THUS REACHED TECHNOLOGICAL MATURITY WITH AROUND 380 REACTOR-YEARS OF EXPERIENCE WORLDWIDE

FAST BREEDER REACTORS

- IT'S COMMERCIALISATION VIS-À-VIS THE ESTABLISHED REACTOR SYSTEMS SUCH AS PWRs AND PHWRs WILL DEPEND ON ITS GENERATING COST IN FULLY DEVELOPED FORM, WITH MATURE DESIGN AND WITH THE BENEFIT OF SERIES PRODUCTION
- FOR THE SUCCESS OF FAST REACTORS, EFFORTS SHOULD BE DIRECTED TOWARDS BOTH REACTOR DESIGN AND FUEL CYCLE.
- THE REACTOR HAS TO COMBINE SAFETY WITH COMPETITIVENESS. THE FUEL CYCLE, IN PARTICULAR REPROCESSING, HAS TO BE AT AN ACCEPTABLE COST.

ECONOMIC VIABILITY

- DESPITE THE INDISPUTABLE NEED FOR FBRs IN INDIA, IT IS WORTH NOTING THAT REACTORS HAVE TO BE ECONOMICALLY ATTRACTIVE IN THE CONTEXT OF PRESENT GOVERNMENT APPROACH FOR INVESTMENT

ECONOMIC COMPARISON(OTHER COUNTRIES)

- THERE IS GENERAL PERCEPTION THAT FBRs ARE LESS ECONOMICAL THAN THERMAL REACTORS
- SPX1 : 2.5 TIMES PWR COST/KW AT THAT TIME
- BN600: LAGGED VVER-1000 BY A FACTOR 1.55 ON SPECIFIC CAPITAL COST
- THE FIRST PROTOTYPE OF FAST REACTORS DID NOT MATCH LIGHT WATER THERMAL REACTORS IN CAPITAL COST OR IN THE UNIT ENERGY COST
- IT IS UNFAIR AND MISLEADING TO MAKE COMPARISON OF PROTOTYPE FBRs WITH MATURED PWR UNITS
- THE PWRs HAVE BENEFITED FROM MANY YEARS OF EXPERIENCE IN CONSTRUCTION AND MORE IMPORTANTLY THE BENEFITS OF SCALE ARISING FROM BATCH PRODUCTION.
- SPX1 AND BN600 WERE THE FIRST OF ITS KIND AND WERE BUILT AS A SINGLE UNIT

APPROACH : PFBR TO FUTURE FBRs ON ECONOMY

- ECONOMIC COMPETITIVENESS IS VITAL FOR COMMERCIAL DEPLOYMENT OF FAST REACTORS
- SIGNIFICANT DESIGN EFFORTS ARE NECESSARY TO REDUCE THE CAPITAL COST OF FUTURE FBRs COUPLED WITH ENHANCED SAFETY
- THERE IS CHALLENGE TO IDENTIFY THE CRITICAL INFLUENTIAL PARAMETERS THAT GOVERN THE OVERALL COST
- EFFORTS ARE CHANNELLED INTO OPTIMIZING THESE WITH FOCUSED R&D, KEEPING IN VIEW INTERNATIONAL EXPERIENCE
- PFBR BEING PROTOTYPE, IS PROVIDING GUIDANCE FOR FUTURE DESIGN AND CONSTRUCTION
- ENHANCED SAFETY AND IMPROVED ECONOMICS ARE TWIN OBJECTIVE

IMPORTANT PARAMETERS

- THE FEW IMPORTANT MEANS TO ACHIEVE ECONOMY ARE AS GIVEN BELOW:
- **COMPACT TWIN UNIT PLANT LAYOUT** : FAVOURABLE EFFECT ON CAPITAL COST REDUCTION. TYPICAL FIGURE APPROX 10%
PFBR CONSTRUCTION EXPERIENCE, SHARING OF BUILDINGS/ FACILITIES WHEREVER POSSIBLE . MODERN METHODOLOGIES FOR PLANNING LAYOUT
- **INNOVATIVE DESIGN FEATURES TO REDUCE SPECIFIC WEIGHTS OF STEELS:**
DESIGN CHANGES IN MAJOR REACTOR ASSEMBLY COMPONENTS WITH VIEW TO OPTIMIZING THE DESIGN AND REDUCING CAPITAL COST
FURTHER THE MANUFACTURING EXPERIENCE WITH COMPONENTS FOR THE PFBR HAS HIGHLIGHTED THE FOCUS AREAS THAT NEED SIMPLIFICATION

KEY AREAS TO ATTACK AND APPROACH

- EXAMPLE: IMPROVED DESIGN CONCEPT FOR A GRID PLATE, ROOF SLAB ETC .
- SIMILARLY OTHER RA COMPONENTS ARE ALSO BEING OPTIMIZED. PRELIMINARY COST ESTIMATE SHOWS REDUCTION OF ABOUT 25% ON SPECIFIC WEIGHT.
- REDUCING EXCESS MARGIN IN DESIGN.

APPROACH

- SIMILARLY ON HEAT TRANSPORT SYSTEMS, FROM BOTH ECONOMICS AND SAFETY, TUBE LENGTH OF SG PLANNED TO BE 30 METERS IN COMPARISON TO 23 METERS FOR PFBR. 6 SG INSTEAD OF 8 SG. 40% REDUCTION IN TUBE TO TUBESHEET WELD AND 25% REDUCTION IN COST. A MODULE WITH FEW TUBES PLANNED TO BE TESTED IN SGTF.
- HOT AND COLD LEG PIPING : 304LN AND 316LN TO 2.25 Cr-1Mo AND MOD. 9Cr-1Mo. DEVELOPMENT OF SODIUM SERVICE VALVES IN Cr-Mo STEEL.

APPROACH

CONTROL ON CONSTRUCTION TIME: LESSONS LEARNT FROM PFBR IN MATERIAL PROCUREMENT AND PLACEMENTS OF ORDERS, REGULATORY CLEARANCES, TENDER PACKAGES, PRE BID QUALIFICATION OF THE INDUSTRIES THROUGH EXPRESSION OF INTEREST MODE, AND MAJORITY(approx. 80%) OF DETAILED DRAWINGS FOR CONSTRUCTION OF CIVIL SAFETY STRUCTURES BEFORE START OF CONSTRUCTION. REDUCTION OF 2 YEARS FEASIBLE.

APPROACH

- **PLANT LIFE** FROM 40 TO 60 YEARS: NEEDS RELIABLE LONG TERM CREEP DATA. SOME PORTION OF THE REACTOR DESIGN ARE GOVERNED BY TIME INDEPENDENT PARAMETERS
- FAVOURABLE IMPACT ON UEC & ALSO ENSURES POWER AVAILABILITY FROM A GIVEN SITE. THIS IS PARTICULARLY OF INTEREST IN VIEW OF LIMITED AVAILABILITY OF SITES FOR NPP.

APPROACH

- **PLANT LOAD FACTOR INCREASE:** DESIGN OF SINGLE RELIABLE TURBINE, ADOPTION OF STATE OF ART DESIGN & MANUFACTURING TECHNIQUES FOR STEAM GENERATORS (STRONG INFLUENCE ON LF), REDUCTION IN OUTAGE TIME DUE TO REFUELING AND IMPROVEMENT IN MAINTENANCE STRATEGY.
- PLF HAS SIGNIFICANT INFLUENCE ON REDUCTION OF UEC.

APPROACH

- **MULTIPLE UNITS AT ONE SITE(SERIES CONSTRUCTION)**

APPROACH

- **FUEL CYCLE COST** : INCREASED PEAK BURN UP HAS A FAVOURABLE INFLUENCE ON FUEL CYCLE COST, REDUCED SIZE OF FUEL CYCLE FACILITY PLANTS AND ALSO REDUCED WASTES OF ALL LEVELS.
- ENHANCED BURN UP IN PHASED MANNER.
- WORKING ON CHANGING THE COMPOSITION AND THERMO-MECHANICAL TREATMENT OF STEEL USED FOR MAKING CLAD AND WRAPPER. SO THE SHIFT IS FROM FUEL TO METALLURGY FOR ACHIEVING HIGHER BURN UP.

APPROACH

- WITH IMPROVED STAINLESS STEEL MATERIAL(D9I SS) THE MINIMUM BURN UP CAN BE TARGETED AS 150 GWd/t .
- SUBSEQUENTLY, WITH DEVELOPMENT OF OXIDE DISPERSION STRENGTHENED(ODS) STEEL THE BURN UP CAN BE FURTHER ENHANCED TO 200 GWd/t

APPROACH

- IMPROVED VERSION OF ALLOY D9
- D9I: 0.25 % Ti + 0.75 % Si+ 0.04% P (WEIGHT %)
- ODS ALLOYS: FERRITIC -MARTENSITIC ODS STEEL
Fe-9Cr-2W-0.1C-0.2Ti-0.34Y₂O₃ (WEIGHT%)

APPROACH

- CO-LOCATION OF FAST REACTOR FUEL CYCLE FACILITY (REPROCESSING, FABRICATION AND WASTE MANAGEMENT) GIVES SUBSTANTIAL FUEL CYCLE COST REDUCTION.
- IT WILL ALLOW BETTER PHYSICAL CONTROL OF THE FISSILE MATERIAL AND REDUCE TRANSPORT RISK

CONCLUSION

- WITH GOOD SUPPORT FROM GOVERNMENT AND COMMITTED INVOLVEMENT FROM ACADEMIA AND INDUSTRY, THE FAST REACTOR PROGRAMME IN INDIA IS POISED FOR HUGE IMPROVEMENT IN NEXT FEW DECADES
- PFBR IS THE FIRST LARGE SIZE FBR BEING BUILT IN THE COUNTRY AND THEREFORE THERE IS SCOPE FOR COST REDUCTION FOR FUTURE FBRs WITH THE STANDARDISATION OF TECHNOLOGY AND SERIES CONSTRUCTION
- GIVEN THAT FBR IS AN IMPORTANT COMPONENT IN INDIA'S QUEST FOR ENERGY SECURITY AND A LINK TO THE EVENTUAL UTILISATION OF THORIUM, THERE IS MERIT IN PURSUING THIS TECHNOLOGY



Thank you