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Editorial

Dear members,
Assalam-o-Alaikum,

Once again we are presenting a number of different issues of importance to our members. Starting with an article by Mr. Suleman N. Khan on the title, "Engineers can save Jinnah's Pakistan" and then closing with an important issue of, "Power System Earthling and Safety" by Mr. Faisal Nafees.

Two Papers are presented by joint venture of son and father from honorable Prof. Dr.T.A. Shami's family on inverter motor system.

In this Era of load shedding an interesting paper has been presented by Dr. Jawad Yunas Uppal titled as "Self-Generation to Combat Power Crisis". A number of papers are also presented touching the renewable energy resources particularly, Solar, Biogas and tidal Power to meet the short fall of electricity.

At the end we all are thankful to you for not criticizing us on our issue throughout the year 2010.
Happy New Year to all of you

The Editor

Engineers Can Save Jinnah's Pakistan

Suleman N. Khan

Preamble

Ever wondered why strategic planning is trashed periodically in Pakistan? Why the nation's hydro endowment & its related national assets are suffering attrition & neglect? India's water war is no longer surreptitious. It is blatant. It is now a cold-blooded campaign. Her transparent interference internally in Pakistan has created an anti-dam lobby within the three smaller provinces. Their open opposition to a second reservoir on the Indus after commissioning of Tarbela Dam (1974) has been suicidal for Pakistan's economy. Punjab, Pakistan's largest populated province and breadbasket has seen its agricultural output stagnate. No thanks to Pakistan's rising population the per-capita agricultural output has fallen in real terms. Poverty & the resulting tensions within the Federation have multiplied. India's internal factor (in Pakistan) & external activities (in Kashmir) have inflicted upto 2010 a financial loss of over a trillion USD equivalent to the PAK economy & it is growing. Due to Pakistan's failure to build multi-purpose dams the desired hydel:thermal ratio has become lopsided; around 30:70. Imported oil based power generation cannot be financially sustainable for the PAK economy. The financial deficit has climbed above USD 10bn for the first time. The national debt servicing is even greater. Textiles our dominant agro based sector has not grown in real terms; merely a hostage to the tripling of the cotton / yarn prices that have inflated the export statistics by around 26%.

India now goes ahead with plans to build 100 + hydro-electric projects on Pakistan's waters flowing through Indian Held-Kashmir. These are the so-called three western rivers: Indus, Jhelum & Chenab. She uses a benign concession in the landmark Indus Waters Treaty of Sep 1960 to justify building dozens of high dams & creating reservoirs in cascade on all three. She could build some non-controversial run-of-the-river hydro-electric power plants (using diversion thru weirs & power tunnels) that return the water flows to the river concerned. Equally disturbing is India's claim on the waters that Pakistan's anti-dam lobby compels it to waste. Pakistan is already since several years facing the inexplicable scenario of drastically shrinking inflows from her western rivers. The hydro based infrastructures being constructed by India in Kashmir permit her absolute control of the surface flows into Pakistan besides creating the capability to divert Kashmir waters into the northern Indian basin. India is building the world's largest single irrigation project stretching from the Indian Punjab (in the west) to Indian Bengal (in the east). A blueprint for history's greatest genocide is unwittingly under implementation?

The tragic symptoms of irrational behavior among Pakistani youth including the bizarre & murderous mission to Mumbai by ten odd PAK militants in Nov 2008 are signs of a despondent people. Such missions will escalate exponentially as a nation comes in the throes of an economic suffocation orchestrated by its upper riparian neighbor. Inhuman policies can bring out inhuman reactions. A sad analogy of Newton's third law of Motion. Indian maneuvering & high handed tactics before the IWT 1960 got them the entire flow of the three Eastern Rivers. It was historically an unprecedented & anti-civil milestone. Equally unforgiveable was that the Pakistani leadership had acquiesced. Today, Pakistan's second largest city Lahore is sinking in its sewage. Its life sustaining Ravi river has become a sewer. It's deep water pumps throwing up arsenic & nitrates far beyond safe limits. Situation in South Punjab is now critical. The anti-dam lobby has ensured reduction of Pakistan's storage capacity to about 8% of its annual surface flows of 145 MAF. Clean drinking water had already become a nationwide struggle. The 2010 floods have demonstrated that lack of mega dams has another ominous dimension. A deadly fifth column exists which the nation has failed to cleanse. Pakistan is economically choking due to its water stressed situation. Yet the Indians project themselves as the aggrieved party.

This paper will focus on the lack of reservoirs & the ignored hydel energy potential. The tragic mistakes clearly orchestrated by our regional adversary & the fifth column within the republic.

PART A: Why Pakistan's economy could not become self-sustaining

We were by 2006 completely dependent on IPPs and the developing “Circular Debt” has been growing menacingly since 1994 due to our unsustainable Imported Energy Policy. The era of massive deficit financing & de-industrialization had arrived. The nation had been trapped in the guise of FDI. How could the thermal based privatization policy lead to lower tariffs? The Statement of Dr. Salman Shah former Adviser to the PM on Finance and Revenue as reported on 30 July 07 to the effect that private companies will build and operate mega dams jolted many of us out of our stupor. Such a model does not exist anywhere. A developing country with an agrarian economy cannot even dream of handing over its irrigation water to the private sector. It is clear that the mistakes committed since 1980s in the operation of Utilities had reached the pits. There is a Chinese saying” when a Utility is in profit the nation is in loss". Tragically we had created a USD two billion financial black hole in our economy by the year 2004 thanks to the unsustainable private thermal generation which was uncapped and based on imported oil. The Independent Power Producers (IPPs) were inducted under the 1994 Power Policy. The devil is in the detail. ***WAPDA/GoP has to pay the fuel cost differential as a pass-thru component***. Today this financial black hole has at least doubled because RFO/HFO (& Diesel fuel) for power generation has crossed + 10 million tons/annum. The creaky infrastructure is overwhelmed. Tragically our hydel development has been dismal and the mega reservoir projects are virtually on hold since Tarbela Dam (1974). The surface storage is now less than 8% of the average 145MAF surface flows. In 2008 & again in 2009 Chairman WAPDA a non-technical bureaucrat clearly advised the Federal Minister to announce the official closure of the Kalabagh Dam project and WAPDA House was the venue for this tragic announcement. Does a nation, a town, a village, a home require "consensus" for its sweet water supplies? Water is life and only an enemy will disagree. Reservoirs are indeed also the lowest cost electric energy resource.

We learnt in 1994 that Pakistan was adopting the California model of IPPs but with radical changes i.e. it was being made unsustainably generous. The California model inflicted great damage to the economy of California within the 90's decade. One had been aware of the basic recommendations of the TASK FORCE on Energy (Jan 94). My serious concern was that any policy based on imported energy, which is uncapped, will destabilize WAPDA therefore the national economy and eventually damage the Federation. Some of us observed that the 1994 Private Power Policy was an evil on the scale of the Agartala Conspiracy which had resulted in East Pakistan's separation from Pakistan. The hibernating HUBCO Agreement of Aug 1992 (negotiated since 1985) was made functional by unfair concessions through amendments upto 1994. HUBCO was the experiment the genesis of which was laid in 1985 on the advice of IMF. To accommodate this 1292MW conventional HFO (furnace oil) fired steam power station WAPDA had scrapped plans for the 1000MW imported coal project to be financed by Canada and froze the extension of Jamshoro thermal P.S. for which the Japanese Government had offered to accept payment in Pak Rupees. Mr. Jam Yousaf Federal Minister of Water and Power gifted a 7 km of beach near Karachi city. A tax free island in Baluchistan. The area gifted is larger than Hong Kong. The World Bank had estimated USD 0.8 mn/MW but later allowed USD 1.2mn/MW. Can we overlook that HUBCO had within 13 months recovered its entire equity of about USD 375mn? It is universally accepted that any IPP controlling +10% of the power supply is a monopoly. This was the period when Bangladesh was purchasing steam power stations with gas fired boilers at USD 350000/MW. Today 15 of the 19 originally sanctioned IPPs under the '94 Private Power Policies are established. Together with the newly inducted IPP's & a privatized KESC the nation is generating about 130bn electrical units per annum; limited only by the financial & infrastructural constraints as discussed. This means about 75% of the total thermal installed capacity and more than 50% of Pakistan's generating capacity is in private hands. We can guess how many more thermal IPPs will be inducted by PPIB, Islamabad.

In contrast both China and India never appreciated this IMF/World Bank concept and did not allow more than 5% of IPP power on imported energy in their national grids. In Pakistan we see that IPPs have throttled the public sector. Surely the OECD Helsinki Accord of 1992 discouraging bilateral financing was not a signal for new imperialism through IPPs? There were some unsung heroes within WAPDA's hierarchy. Foremost among them being Mr. Javed Akhtar, WAPDA's brilliant Member Power who was squeezed out in May 1994 several months before his 60th birthday. It is not a co-incidence that the IPPs have found an opportunity to provide over 66% of Pakistan's electric power taking advantage of the low hydel generation cycle. This is unsustainable and the dire predictions made in 1994-99 period by several of us have been unfortunately accurate. Mass industrialization is now impossible. This is the age of aluminum but we cannot have an aluminum smelter since it is not viable with expensive electric power. Similarly we are excluded from several basic industrial sectors. The developing world's most expensive power is now perforce being supplied to domestic users (over 60%) then to industry (around 28%) and agriculture (around 10%). The IPPs propaganda machine is so effective that even sensible people are heard expressing their gratitude for the great contribution of IPPs oblivious that imported fuel based IPPs are playing havoc with our economy. Where in the world do investors get a blank cheque for their capital cost repayments and pass-thru increase in fuel prices all indexed to U.S CPI as allowed in the 1994 Thermal IPP policy? Projects that were granted without competition for a minimum guaranteed profit over a thirty years period found ways to increase their IRRs through several routes. The capital costs of the projects (including HUBCO) being a direct liability of the GoP. Who could resist over invoicing if someone else has to pay the bill? Yes there was to be no taxation on the income of IPPs although they are Pakistani companies. The US 6.5$ tariff was a bluff as furnace oil is pegged at a rate (Rs 2350/ton) which is around 6% of today's rates. ***The difference payable by GoP/WAPDA.*** Since 2006 we see rental power also being contracted. Imported oil cannot bring prosperity. The fuel would be provided free (pass-thru) to the RPP operating the rental power station. How can anyone justify the actions of former Prime Minister Shaukat Aziz to disallow new WAPDA/Gencos thermal projects in the public sector? A 1000 MW of additional public sector power would have made a difference especially in the perception of IPPs stranglehold. This was precisely what Mr. Shaukat Aziz could not allow. He treated public sector generation with contempt. He diverted 110mmcfd of Guddu's gas quota to his friends operating Fatima Fertilizer. He denied 300mmcfd to Muzaffargarh TPS. When IPP Rousch failed to run on HFO he diverted GENCO gas quota to operate the IPP. He ensured over 250mmcfd for private transport and ignored public sector CNG based Mass Transit. He diverted over 20% of national gas resource from power generation. Today the new round of Fast Track IPPs based on thermal energy are negotiating and re-negotiating with GoP/PPIB, taking maximum advantage of the shortages and load-shedding. All this while the public sector is kept blocked since 1988. HUBCO set the precedent. The post 9/11 events brought an artificial respite for the economy giving a false indication of prosperity. The illusion could last only till the aid was flowing freely.

A desperate economic situation has engulfed Pakistan since 1994. Hopefully you will agree with Edward Burke "The only thing for evil to triumph is for good men to do nothing". I salute the wisdom of late Engr. Dr. Ghulam Safdar Butt (Lt. Gen. Rtd) the hero of the KKH saga who helped to open the Northern Areas for economic development. He made the international conference of 9 Feb 98 possible and was an inspiration till his passing away in early 2006. I also salute the courage of several patriots including Mr. Hidayatullah whose conscience reportedly resulted in his exit as auditor of Hub Power Co. Mr. Aziz Qureshi an ex-banker who was the moving spirit in WAPDA's short-lived legal challenge to Hub Power Co's indiscretions allegedly committed in their first 2 years of operations (1996-98). Mr. Salahuddin Rifai former G.M WAPDA / NTDC who ensured economic despatch without fear & favour. The rogues can also be identified. Above all the Indian factor emerges very strongly. When the GNP of a nation does not rise in tandem with its GDP (due to excessive outflows of profits and dividends) we have economic and social upheavals. The British Imperial masters had increased India's GDP. After a while they had become a liability inspite of a benign rule. Secondly we all know that economic inequities lead to political and social upheavals. Historically FDI has often been misdirected and used as a tool of exploitation. ***In Pakistan's case we are no longer having a self sustainable economy primarily due to our tragically flawed policy in the three crucial areas i.e. civilian engineering industry sustenance of our irrigation assets and last but not the least our treacherous energy policy. Clearly FDI is not always healthy for the recipient. FDI should be accepted on a rational and selective basis. The Economist of 02 Feb 2008 reported that finally India has eased limits on FDI in six industries only.*** These included commodity exchanges, credit information firms, oil refining, titanium mining and parts of aviation concerning only cargo planes and services including relevant pilot training.

It was on 09 Feb 98 that I had convened a conference on Water Reservoirs in the National Economy at Islamabad. The morning session was presided by the Prime Minister and during the full days discussion all major aspects of our predominantly irrigated agriculture, hydro energy potential and related aspects were addressed. The legendary S.S Kirmani Sahib was unable to attend but his kind fax message was read out. Three months later he was summoned by the Creator. His message remains most relevant. The guest from Turkey Mr. Irfan Aker made an inspiring analysis of the Greater Anatolian Project (GAP). An enlightening talk was given by Dr. Peter Grein of Switzerland on desilting of reservoirs and his experiences in China. Presented late Maj. Gen. (Rtd) Fazle Raziq late, Lt. Gen (Rtd) Dr. Ghulam Safdar Butt and Engr. Hissamuddin Bangash as speakers. The guest speaker Engr. Khalid Mohtadullah (Member Water WAPDA) had discussed the benefits of reservoir construction and explained the details of the IBIS (Indus Basin Irrigation System). There was a prolific technical session in the afternoon presided by eminent irrigation engineer of Sindh Mr. Elahi Buskh Soomro then Speaker of the National Assembly. The expected pit-falls in the building of Diamer -Bhasha and the near impossible status of Katzarah/Yago/Skardu on humanitarian and ecological grounds were also deliberated by several experts. A resolution was unanimously approved by the delegates for the construction of atleast one reservoir on the Indus without further loss of time. Everyone agreed that some 16 years had already been lost as 10 years after Tarbela (1974) a new reservoir's construction should have started and would have been available by 1990. In financial terms a staggering wastage of around USD 230bn equivalent between 1990 and 2010 & due to non-availability of a second reservoir on the Indus that could have kept our economic growth far ahead of our population increase. A near hopeless sociological situation as experienced today would have been averted. The arbitrary private thermal power policy of 1994 based primarily on imported oil after imposing a ban on increased public sector generation was a national tragedy.

In Dec 1998 in the office of the COAS I had presented my essay "Pakistan's Strategic Federal Assets". In my long meeting I had exhorted all present in his office that WAPDA must be kept intact inline with its charter of 1958. I repeated this analysis in March 1999 during the second marathon meeting with him and several of his military colleagues. On his desire there was a well attended seminar at GHQ in April 1999 which was coordinated by Lt. Gen Jahangir Nasrullah (Engineer-in-Chief). My team had included some elders of the Feb 98 Water Conference including late Lt. Gen (Rtd) Dr. G.S. Butt, Engr. Hisamuddin Bangash and Dr. H. Grein of Switzerland an academic associated with ETH Lausanne. No one can object to WAPDA's modernization. It is modeled on the TVA which is America's most successful civilian project. The willful destruction of its balance sheet is a national calamity. It was only eight years ago when the Indian Army COAS declared and translated verbatim "Every proposal in opposition to Kalabagh Dam is like a new nail in the coffin of Pakistan's defense capability". A three member Indian delegation to an Islamabad conference declared that Indus Waters Treaty is superfluous!

It is quite apparent that the induction of non-technical bureaucrats in Engineering Organizations has been a major factor in the nation's economic plight. In WAPDA's nascent developing stages it was fortunate to have had visionaries such as Ghulam Ishaq Khan, Ghulam Faruque Khan & I. A. Khan. They were trained to seek advice & work as a team. They could study the financial impact of every step. Today the seat of Chairman WAPDA has been reserved for a political group whose declared policy is "No more reservoirs on the Indus". No wonder the Chairman does not spend more than a week in Lahore. He demands that the 96MW Jinnah Low Head project be expedited while the 3600MW KBD, few km upstream is willfully forgotten.

Part B: The Hydel: Thermal ratio holds the key to economic independence.

Are you aware that India has effectively lobbied with the multilaterals about the Northern Areas being part of Greater Kashmir? She has blocked World Bank financing for mega projects such as Diamer-Basha Dam & Bunji HPP due to this linkage. Why no one appealed against this AJK High Court decision? Indian machinations & anti- Pakistan activities are no longer analyzed & published by most of our media groups. Real peace & "shanti" cannot be achieved if one party is after the very existence & survival of the other. Let the Engineers of all disciplines in partnership with scientists and civil society compel the major media groups thru force of facts & logic that there can be no peace until the Indians abandon their hydro offensive in all its manifestations. Kashmir was always recognized by our elders as the "jugular vein" of the nation. Why are we allowing the fifth column to conceal these deadly realities? While we address this menace and compel the government of the day to appeal this "Greater Kashmir" Judgment by an AJK High Court Judge we may rethink our national strategy for a sincere Fast-Track hydel development campaign. The engineers must give this the top priority. Let us assume that reservoirs on major rivers are presently not being allowed by political elements & their bureaucrat nominees. A deadly squeeze on the economy is therefore visible. Major reservoirs have three purposes viz, Irrigation Water, Electrical Energy & Attenuation of Floods. Comrades are requested to study the WRDC article on proposed CIBSA as a counter to the ICID menace at www.wrdc.com.pk. Our Sindhi brethren infact drink canal water inspite of the pollution. Their ground water is brackish & full of pathogens which makes it unfit for human consumption. In fact whichever part of Pakistan will be denied Indus Waters its economic growth will be nearly impossible & extremism will follow. At best in the next five years we can expect about 500MW tunnel/run-of-river projects to be additionally commissioned providing around 2.5bn units per annum. Neelum Jhelum tunnel project is around 10 years away. Procurement of TBMs seems to be the present obsession of the WAPDA Chairman and his colleagues inspite of the dubious technical benefits. We are all familiar with the hydro power potential river-wise summary that is periodically issued by WAPDA including large reservoirs. Below are the recent figures in chart form.

Sr. No.	River / Tributary	Power (MW)
01.	Indus River	37780
02.	Tributaries of Indus (Northern Areas) & NWFP	6006
03.	Jhelum River	3143
04.	Kunhar River	1435
05.	Neelum River & its Tributaries	1844
06.	Poonch River	397
07.	Swat River & its Tributaries	2371
08.	Chitral River & its Tributaries	2282
09.	Schemes below 50MW on Tributaries	1055
10.	Schemes below 50MW on Canals	408

Part C: Indian hydro policy in Indian Held Kashmir (IHK)

Let us now discuss the rising menace of India's Northern Canal Project. What this USD 200Bn + project means for the future of our children. The real implications of Baghliar Dam, Kishin ganga Barrage and the infrastructure on the Wullar Lake. Being in the peace mode we should surely advocate a peaceful accord. There has to be a consensus internally and thereafter a recognition by the world community of our historical apprehension that Kashmir is a water related issue. Since 1947 we have failed to surmount the Indian factor. India must respect in letter and spirit the tenets of the "Indus Waters Treaty 1960". It is sacrosanct. ***Tragically the Indians are now guilty of laying the groundwork for genocide of our nation through the ongoing theft of Pakistan waters.*** India is in the process of planning & constructing 171 hydroelectric power projects (HPP) in Indian Held Kashmir (IHK). Atleast 42 projects on the three western rivers and their tributaries are already in operation. Atleast 14 are under construction & remaining 115 in advanced stages of planning & design. Indian official strategy is to achieve +28,000MW installed hydroelectric capacity in IHK before 2020. This fact has been known since many years.

There are 17 projects in operation on Chenab & its tributaries. Three more are under construction (including Baghliar II). Another 56 are in advanced stages of planning & design. The IHK projects in operation on Chenab main include Salal Dam & HPP (345MW) as well as Baghliar I HPP (450MW). The Salal Dam for example has considerable storage capability which can be mis-operated in violation of the Indus Waters Treaty (1960) and could seriously affect the inflow into Pakistan (at Maralla). Secondly on Jhelum& its tributaries another 13 projects are in operation, 8 projects under construction & 43 HPP in advanced planning stages. Work on their Wullar Barrage Project was suspended; the URI HPP (480MW) is operating. Pakistan has taken a serious view of the Kishen ganga HPP project as it is in blatant violation of the IWT 1960. It includes the transfer of Neelum waters into Jhelum & is a violation of the IWT 1960, Annexure D para 15c(iii) & Annexure E para 10. Neelum is a tributary of the Jhelum. The completion of Pakistan's Neelum Jhelum HPP / tunnel project will mean that India cannot operate its Kishen ganga HPP as Pakistan has the right to the uninterrupted use of the western rivers. Another interpretation is diabolical. There is no race between the two parties. Thirdly on the Indus & its tributaries 12 smaller projects are operating, 3 under construction & 16 planned.

It is apparent that by constructing these HPP in cascade, creating substantial storage at any given time, Indian would seriously disturb the flow (and timing of the flow) of the western rivers in clear violation of the IWT 1960. Such activity would have serious repercussion on Pakistan's future reservoir projects such as Kalabagh Dam, Akhori Dam & Diamer Basha Dam. Also due to India's Kishen ganga HPP water diversion aspect there would be a serious impact on the power generation potential of the Neelum Jhelum HPP. We cannot remain passive.

Mr. David Lilienthal, a founding Director of the TVA was dispatched to the subcontinent by President Truman and had predicted these tragic events in his August 1951 report to PM Liaquat Ali Khan. In the present decade Prof. John Briscoe of Harvard University has published two major books on the subject of Indus Waters. His recent article "War on the Indus" is highly critical of Indian projects in IHK as they blatantly violate the IWT 1960 by disturbing the flow and timing of the flows of the western rivers. With dozens of HPP projects the cumulative gross storage at any moment of time will be several MAF & inherently lethal for all downstream infrastructure projects including the Indus Basin Irrigation System (IBIS). Pakistan has priority and exclusive rights (with minor exceptions) over the waters of the western rivers and this issue is non-negotiable. Pakistan's anxiety to secure these rights had resulted in the historic blunder within the IWT 1960; of granting India the 100% water rights of the three eastern rivers (Ravi, Sutlej, Beas). India has to be made to respect Pakistan's exclusive rights on the western rivers.

Conclusion:

WAPDA the economic backbone of Pakistan has to be made viable. A technocrat from the civil or military hierarchy must be inducted to stop the rot. The engineering community must play its role in building public awareness on the "Greater Kashmir" game which has blocked our mega projects. KBD is a quick & economical lifeline for Pakistan and has to be built at all costs. It's perfect location for both irrigation & energy production are indisputable. Tarbela Dam's hydraulic efficiency & energy output is vastly enhanced if there is a downstream dam working in cascade. Imported oil based IPPs & RPPs have to be pushed out asap from the PEPCO system.

The anti-dam lobby has ensured reduction of Pakistan's storage capacity to about 8% of its annual surface flows of 145MAF. Pakistan is economically choking due to its water stressed situation. Pakistan needs water for its agricultural and energy needs. Substitution by imported energy (oil) is not sustainable. The national objective has to be an annual increase of 2% in the surface storages for the next 15 years and within 10 years to achieve the desired Hydel:Thermal ratio of 70:30 from Hydro Reservoirs & Run-of-River projects. Our sovereignty is at stake.

Our mission should be to focus Indian and world attention on the spirit of the Indus Waters Treaty 1960 so that violations & transgressions can be checked if not totally eliminated ab-initio. Indians must become good upper riparian neighbors. We have missed several opportunities. Renegotiation of the IWT 1960 is not possible because the Indians will not discuss the ownership of the three eastern rivers. Indian official strategy since 1947 is leading to history's greatest genocide and this must be reversed for the sake of all people in the region and beyond. Mr. John Briscoe correctly hopes for an Indian Mandella. Let us all sincerely pray for one before it is too late. Both resultant scenarios are frightening. An economically crippled Pakistan which, God forbid, would be prone to separatist intrigues **or** nuclear Armageddon.

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Results of Modeling and Simulation of an Inverter-Motor System.

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Abstract

This paper presents a practical method to construct, for simulation purposes, a comprehensive model of a inverter driven motor system. Also included is high frequency modeling of a seven-conductor power cable engaged between the inverter and motor. For the simulation, all model-components of the system are integrated in accordance with the experimental inverter-motor system. Several previous papers focusing on this issue have assumed various cable parameters like characteristic impedance or cable distributed network elements whereas in this paper, we have proposed a technique to experimentally evaluate the power cable parameters essential for modeling purposes. Experimental and simulated results for an industrial 400-V, 15-kW induction motor are presented. The results satisfactorily substantiate the viability and effectiveness of the proposed simulation.

Index Terms PWM inverter, travelling-waves reflections, differential-mode filter, seven-conductor long cable simulation.

I. Introduction

Precise simulation of real-world components can be achieved by comprehensive modeling. A technique that provides accurate, quick, and economical, parameter extraction method becomes indispensable for the academia, and research and development industry. The motivation of this research is to develop a simulation model of the inverter, differential-mode filter, a seven-conductor long power cable, and an induction motor for simulation purposes. The modeling of the cable includes a per unit length model that can be utilized to simulate cables of different lengths. Another aim is to address problems encountered while building the simulation model for example inverter to ground leakage current paths, and the simulation process so that the results are generated close to actual.

This research becomes more relevant when modern power-electronic switching devices like IGBTs are incorporated in the simulation model along with the long cable. IGBTs have outstanding performance and are competitive in terms of cost, reliability and EMI interference. The small switching time of IGBTs and the long cable lengths are the key problem of oscillating over-voltages at the cable output terminals. The oscillating over-voltages are an unsurpassable problem and has become a significant research area. The traveling wave and reflection phenomena usually explains the cause of oscillating over voltages at the motor terminals [1,3]. The magnitude of the over voltage depends upon the PWM pulse rise time, length of cable, the degree of mismatch between the cable characteristic impedance Z_O, and the motor input impedance[4,6]. This paper examines the inverter switching mechanism, filter design, cable characteristics, and motor over voltages. Long cable distortion has also been considered as it is essential for detailed analysis of the over voltage occurrence. As a result, a seven conductor lossy-transmission line cable model is proposed. A high-frequency motor model is presented and it is used to verify the over voltages in long cable utility. The system model presented here will be used to simulate the over voltage occurrence and will be compared with the experimental measurements. Comparison of the experimental and simulation results include inverter output voltage, motor input voltages.

The simulation approach is beneficial for the over voltage analysis as it provides an adaptable method to understand the inverter internal operation, the design of the differential-mode filter, behavior of the cable, and behavior of the motor. This model will help in future research of filter design, comparison of filters, cable behavior, and identification of various variables like voltages, currents and wattage loss of elements used in the process. A few assumptions related to the inverter-cable-motor model are as follows,

1. The conductors in the cable are symmetrically assembled.
2. Due to the symmetrically assembled twisted-pair conductors, the mutual inductance of individual conductor is neglected in the simulation model.
3. The skin-effect has been ignored and a lossy-transmission line model is used instead.
4. The motor shaft is decoupled for any load.

The paper is structured as follows. Section II describes a brief overview of the experimental system. Section III presents the model of the IGBT based inverter. Section IV discusses the 100-m power cable distributed network parameters. In section V a high-frequency model of the induction motor is discussed. Section VI compares the performance of the simulation model versus the experimental results. Conclusions are described in section VII with some intended directions for future work.

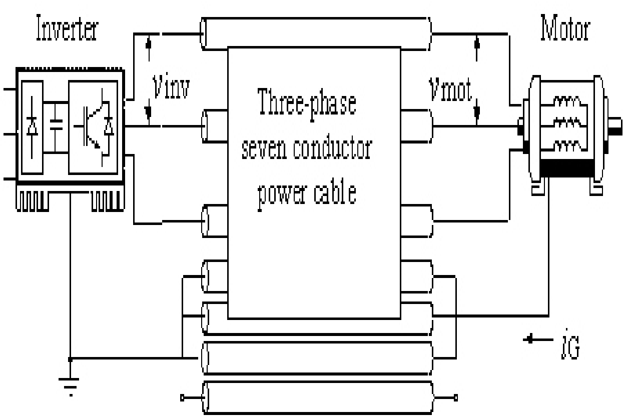


Fig. 1 Overview of the experimental system depicting the inverter with 100-m three-phase seven conductor power cable and the motor.

II. Overview Of The Experimental System

Fig. 1 displays the inverter-driven motor experimental system in which a one hundred-meter long seven-conductor power cable is connected between an inverter and a three-phase induction motor. The cable complies with JISC3312-600VPVC insulated and sheathed. The induction motor is a general purpose three-phase, 400-V, 15-kW four-pole machine. Table I, presents the detailed specifications of the inverter-driven experimental system. The observed instantaneous inverter terminal and motor terminal voltages are represented by v_{inv} and v_{mot}, respectively.

III. Development Of The Inverter Model

A commercial two-level inverter is used in the experimental setup. It houses IGBTs as the power electronic device that drive the motor. Modeling of the inverter is crucial because the power pulse that initiate from the inverter becomes a traveling-wave, oscillating back and forth between the inverter and motor over the cable length. Therefore, the turn-on and turn-off time of the IGBTs have a significant impact on the traveling-wave. Both these switching times are taken into account in the inverter model. Fig. 2 shows the corresponding inverter circuit model that is employed in the simulation system model whereas inverter model parameters are fed to the simulation software. In addition, the simulation model of the inverter includes the inverter PWM scheme, PWM waveform carrier frequency, IGBT turn-on and turn-off dynamic resistances. The leakage capacitance C_{BL} that exists between the inverter heat-sink and the electrically insulted power electronic substrate as shown in Fig. 2 [7,9].

INVERTER SPECIFICATIONS	
Input Voltage	400V
Inverter Type	Two-level Inverter
PWM Switching Frequency	7.5 to 15kHz
Output Switching Device	IGBT
IGBT Switching Time	200ns
CABLE SPECIFICATIONS	
Peak Voltage	1000V
Length	100m
Insulator	Polyvinyl Chloride
Number of Conductors	7 Conductor
Conductor Outer Diameter	2.5mm
Cable Diameter	16.5mm
Insulation Thickness	0.8mm
Sheath Thickness	2.1mm
INDUCTION MOTOR SPECIFICATIONS	
Rated Voltage	400V
Rated Power	15kW
Number of Phases	3
Number of Poles	4

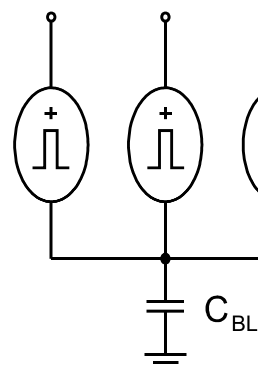


Fig. 2. PWM inverter simulation model with power electronic substrate to heat-sink leakage capacitance

IV. Development Of The 100-m Three-phase Seven Conductor Power Cable Model

The model for simulating the 100-m three-phase seven conductor power cable is highly important. This model is a part of the load presented to the inverter. The length of cables i.e., a hundred meters, requires proper modeling and there is no option for mere estimations. The authors have presented a research paper [10] that discuss in detail the parameter extraction and simulation modeling process for a long three-phase seven conductor power cable. The resulting simulation model as discussed in [10] is used here to simulate the power cable.

V. Development Of The Motor Model

To build a model of the three-phase induction motor, its parameters are to be calculated. These calculations are done using the two-port network theory. Fig. 3(a), shows the motor model, the three-phase input terminals are joined together resulting in a two-port network as shown in Fig. 3(b). Where in Fig. 3(b), Z_a represents the parallel connected three-phase stator windings' impedances, Z_b represents the lump stator to ground pararistic impedance and Z_c represents the lump impedance from neutral to ground.

Four tests are conducted on the actual motor to build a motor model shown in Fig. 3(a). In each test the three-phase input terminals are joined together. In the first test, a LCR meter is connected between the input terminals and ground. The neutral and the ground are left open-circuited, this gives the value of Z_{O1}. For the second test, the LCR meter again connected between the input terminals and ground while the neutral is short-circuited with the ground, this gives the value of Z_{S1}. In the third test, the LCR meter is connected between the neutral and ground whereas the input terminals and the ground are open-circuited, this gives the value of Z_{O2}. Finally, for the fourth test the LCR meter is connected between the neutral and the ground but the input terminals and the ground are short-circuited, this gives the value of Z_{S2}. This two-port motor model can be transformed back to the per phase motor model [10, 11].

VI. Experimental And Simulation Results

To validate the system model and its parameters, the inverter-motor system is first experimentally tested. In first test, the circuit is connected as shown in Fig. 1. It is observed inverter terminal voltage v_{inv} produces oscilating line-to-line overvoltages at the motor terminals, v_{mot} . The results of the experimental test are shown in Fig 5(a).

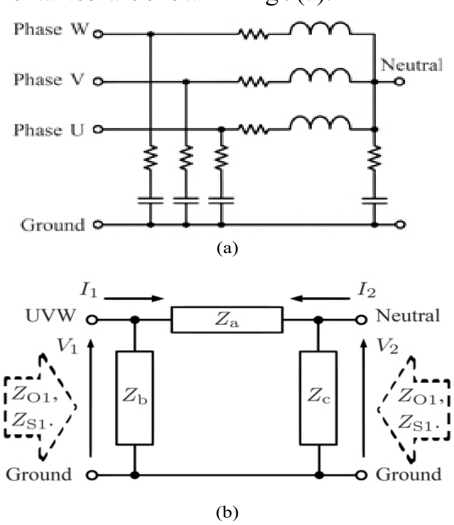


Fig. 3. (a) Circuit model for the motor. (b) Two -port network model of the motor.

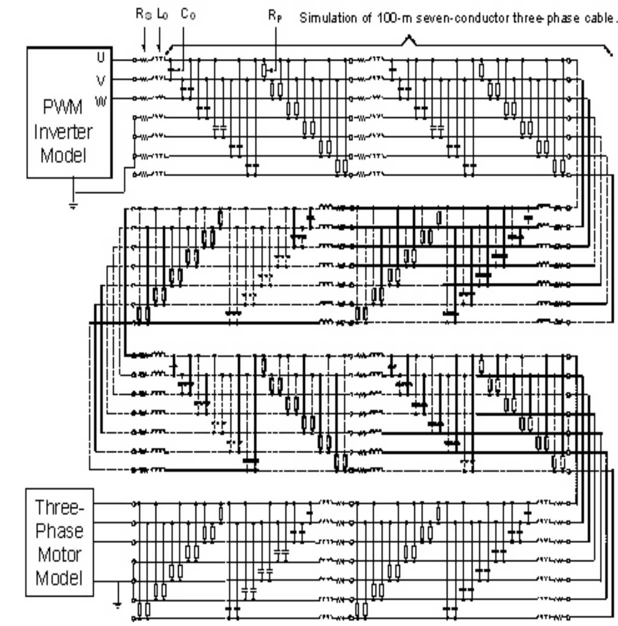


Fig 4 Simulation model of the inverter, 100-m three-phase seven conductor power cable and the motor.

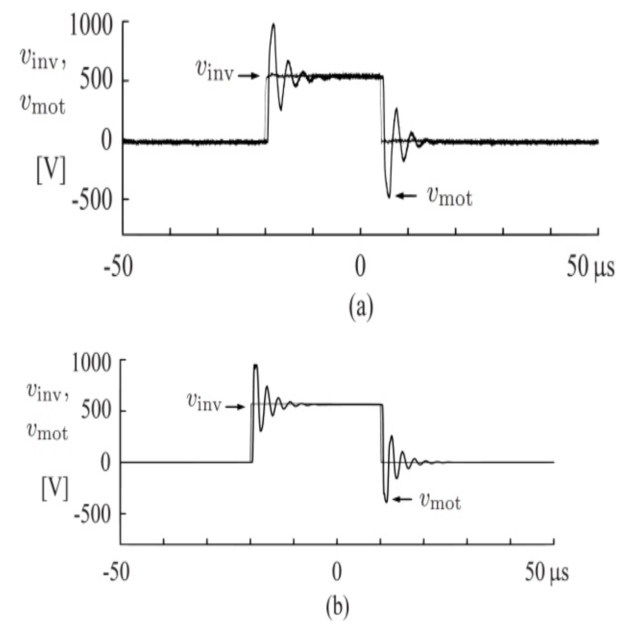


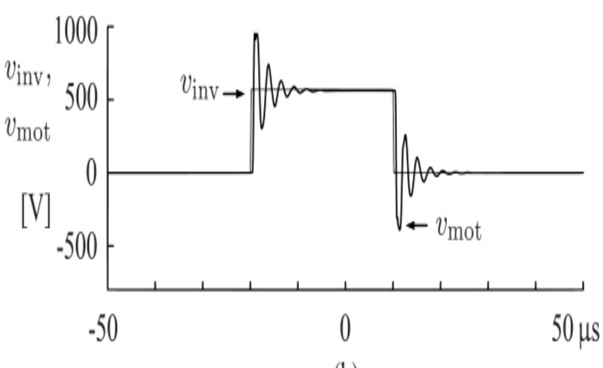
Fig.5.Comparison between the 100-m long three-phase power cable experimental and simulation results. (a) The experimental results. (b) The simulation results.

Fig. 4 shows the simulation models of the inverter, 100-m three-phase seven conductor power cable, and the motor as been built and simulated in Orcad™-Capture software. The inverter carrier frequency is adjusted to 7.5 kHz, the IGBT rise and fall time are 180 ns and 200 ns, respectively. The inverter pulse widths are controlled via generating a true PWM wave. To simulate the 100m cable, the cable has been broken into 100 units. Each unit represents a 1m cable length and the impedance parameters are adjusted accordingly. The output terminals of simulated cable are connected to the motor model.

Fig. 5 presents the comparison of the experimental and simulation results. The satisfactory agreement between the experimental results to those of the simulation verify the inverter-driven motor system model. Fig. 6 presents the simulation results when a differential-mode filter is connected between the inverter and the 100-m power cable. The differential-mode filter is combination of a resistor and an inductor connected in parallel. The differential-mode filter values are as R = 33Ù, and L = 30 ìH.

VII. Conclusions

This paper has proposed a model for simulating a inverter driven motor using a seven-conductor long cable. The simulation model has been used to analyze the filter behavior, long cable behavior, and overvoltage phenomena. The inverter electronic substrate to heat-sink leakage capacitance, inverter switching times, IGBT turn-on and turn-off resistances, and inverter switching scheme can be adjusted to approximate the actual inverter. The proposed simulation model can be used in the verification of new filter networks. Using the simulation, the degree of mismatch between the filter and cable characteristic can be determined and effective design of filter can be suggested. Along with this, filter losses and efficiency can be estimated. Carefully inspecting all the waveforms of Fig. 5 show that the simulated results weakly deviate from their respective experimental results at the edges. This may be due to the assumptions described earlier and a discussion on this is left for future work.



(b)

Fig. 6. Simulation results of inverter voltage v_{inv} and motor input voltage v_{mot} when a differential-mode filter is connected between the inverter and 100-m power cable.

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Quotation

* To the dull mind all nature is leaden. To the illumined mind the whole world sparkles with light.

Ralph Waldo Emerson

*. The true, strong and sound mind is the mind that can embrace equally great things and small.

Samuel Johnson

* The height of cleverness is to conceal one's cleverness.

Francois de La Rochefoucauld

*. Knowledge itself is power.

Francis Bacon

* In expanding the field of knowledge we but increase the horizon of ignorance.

Henry Miller

* Integrity without knowledge is weak and useless and knowledge without integrity is dangerous and dreadful.

Robert Quillen

*. The greater our knowledge increases, the greater our ignorance unfolds.

* The acquisition of knowledge is the mission of research, the transmission of knowledge is the mission of teaching, and the application of knowledge is the mission of public service.

James A. Perkins

*. The greatest obstacle to discovery is not ignorance - it is the illusion of knowledge.

Daniel J. Boorstin

Performance Evaluation of Long Term Evolution (LTE) Mobile Broadband Standard's Physical Layer

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University of Engg. & Technology Taxila

Abstract

This paper describes the implementation of Physical Layer of Long Term Evolution (LTE) in the downlink direction. The main purpose of this paper is to demonstrate how the user data is transferred from base station to mobile station (downlink). The downlink transmission is based on OFDMA. The implementations are done on MATLAB. In the implementation model of LTE Physical layer in the downlink direction, we have designed the LTE Transmitter and Receiver with mobile channel between them. The simulations are carried out to investigate the effect of several mobile radio channel impairment factors in the form of Bit Error Rate (BER), Symbol Error Rate (SER) and Average Mean Square Error (MSE) vs. Signal to Noise Ratio (SNR). In MIMO technology, Throughputs of the LTE system in the downlink direction are also measured with respect to SNR.

Introduction:

LTE is a new air interface technique for UMTS. It is based on OFDM for downlink transmission and SC-FDMA for uplink transmission.3rd Generation Partnership Project (3GPP) has recently standardized the Long Term Evolution (LTE) which is the successor of the Universal Mobile Telecommunication System (UMTS).In the physical layer, 100Mbits/s and 50 Mbits/s are the targets for downlink and uplink peak data rates respectively when operating in a 20MHz spectrum allocation. The experimental results show that the throughputs of the LTE physical layer and MIMO technology improve the spectral efficiency. There are some other benefits of LTE which are explained below.

The downlink transmission scheme of LTE is based on Orthogonal Frequency Division Multiple Access (OFDMA). It divides the whole available bandwidth into a set of many flat fading subchannels. The advantage of these subchannels is that in the case of MIMO transmission optimum receivers can be made with less complexity. OFDMA also supports the frequency scheduling, trying to assign only good subchannels to the users. This provides the large throughput gains in the downlink transmission due to the multi use environment. Another benefit of LTE is the X2-interface between base stations. This interface is used to minimize inter-cell interference.

Due to the high peak rates and large range of data rates of the LTE physical layer, alongwith the combination of strict latency requirements and the new simplified architecture make the LTE attractive for cellular networks.

The LTE Physical Layer (PHY) is highly efficient and promising source of transferring both data and control information between an enhanced base station (eNodeB) and mobile user equipment (UE). LTE PHY introduces some advanced technologies that are new to cellular applications. The LTE PHY uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA allows data to be directed to or from multiple users on a subcarrier-by-subcarrier basis for a specified number of symbol periods. LTE uses both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) in order to separate UL and DL traffic. Majority of the deployed systems will be FDD depending on the market preferences.

The channel estimation between LTE transmitter and receiver is based on basic model. The channel performance is tested by changing the average Signal-to-Noise Ratio and plotted against the performance measure. This is obtained by changing the variance of the additive noise and then running channel estimation for the fixed amount of OFDM frames. The performance of the wireless channel between LTE transmitter and receiver is measured in terms of mean square error (MSE), Symbol error rate (SER), block error rate (BLE), bit error rate (BER) and throughput vs SNR to obtain these performance measures.

Literature Review

LTE uses efficiently the available spectrum with channel bandwidths from 1.25 Megahertz (MHz) to 20MHz.It also offer an Internet experience closer to the wired broadband connection. An additional upgrade, LTE advanced, would enable peak data download rates of over 1 gigabit per second (Gbps) to support 4G.

LTE Physical Layer Properties

The properties of the physical layer are used to determine the performance characteristics of a cellular system like data rates, latencies and coverage. The LTE uses orthogonal frequency division multiplex (OFDM) due to the robustness against multipath fading. There are the advantages of low complexity receiver design and operation of LTE in different system bandwidth up to 20MHz.OFDM supports multi-user access because subcarriers can be allocated to different users.

The LTE uses the Single-carrier frequency division multiple access (SC-FDMA) in the uplink transmission. Compared to the OFDM, this OFDM variant allows the improved peak to average power ratio which enables more power efficient terminals.

LTE downlink physical layer

LTE uses the OFDM in the downlink transmission which is robust against multipath fading. OFDM systems break the whole available bandwidth into number of narrower subcarriers and transmit the data in parallel streams. Each subcarrier is modulated using different levels of QAM modulation like QPSK, QAM, 64QAM or possibly higher orders depending on signal quality. Since data is transmitted in parallel form rather than serial, so the OFDM symbols are much longer than symbols on single carrier systems of equivalent data rate[1].

Basically, there are two very important considerations in the OFDM systems. First a cyclic prefix is appended with each OFDM symbol that is used to eliminate ISI. The second consideration is that the sub carriers are very tightly spaced to make the efficient use of available bandwidth. That will eliminate the problem of Inter carrier interference (ICI). These two features are closely related in the LTE. In order to realize the effect of multipath distortion in the OFDM system, it is necessary to consider the signal in both frequency and time domain.

Frame Structure

There are two possible radio frame structures [11].

1) Generic Frame Structure

The each radio frame having the length of 10 ms consists of 20 slots of duration Tslot = 0.5 ms, and having the numbering from 0 to 19.A subframe consists of two consecutive slots. For FDD, all the subframes are available for downlink and uplink transmission having 10 ms duration. In FDD, the uplink and downlink transmissions are separated in the frequency domain. For TDD, the subframe is either allocated to downlink or uplink transmission. The first subframe is always allocated for the downlink transmission.

2) Alternative Frame Structure

This frame structure is only suitable for TDD. Here in this case, each radio frame is divided into two equal and similar half frames with duration of 5 ms each. There are seven slots in each half frame which are numbering from 0 to 6. There are three special fields, one of them a guard period (GP). Slot # 0 and another special block (DwPTS) are reserved for downlink transmission and slot # 1 and last special block (UpPTS) are reserved for uplink transmission.

LTE uplink physical layer

SC-FDMA is a modified version of OFDMA. Just similar to the OFDMA, The SC-FDMA transmitters uses the orthogonal sub-carriers in order to transmit the information symbols. But as opposed to the OFDMA systems, they transmit the sub-carriers sequentially. The advantage of the SC-FDMA is that the signals have the lower peak to average power ratio than that of OFDMA signals [13].

The function of the SC-FDMA system is that the transmitter in SC-FDMA transforms the binary input signal to the sequence of modulated sub carriers. There are many similarities between these two systems but the difference is the use of Discrete Fourier Transform (DFT) in the SC-FDMA transmitter and the Inverse DFT in the SC-FDMA receiver. Due to this fact, SC-FDMA is also known as DFT spread OFDMA.

Multiple-input multiple-output

In a Multiple Input and Multiple Output Systems, both sides of the communication link has multiple receiving and transmitting antennas. When the data stream is transmitted, then it can be divided between the multiple antennas to enhance the transfer rate of the data stream. Then this technique can be used to enable multiple UEs to transmit and receive simultaneously. Large coverage, capacity and data rates are some benefits from this technology.

The Baseline antenna configurations have two transmit antennas at the Base Station and two receive antennas at the Mobile Station. There are the maximum possibilities of four transmit and four receive antennas [5]. The MIMO mode is restricted by the MT capability, and is determined according to the slow channel variation.

In LTE, Basically the configurations have two transmitting and two receiving antenna per cell on the eNB and there are two receiving and one transmitting antenna per UE. 4×4 antenna configuration is also be considered.

Performance Evaluation

The given scenario is a downlink direction of LTE wireless system. This scenario consists of a set of mobile terminals (MT) which are connected to the Base Station (BS) or E-NodeB through frequency-selective radio channel as shown in figure below.

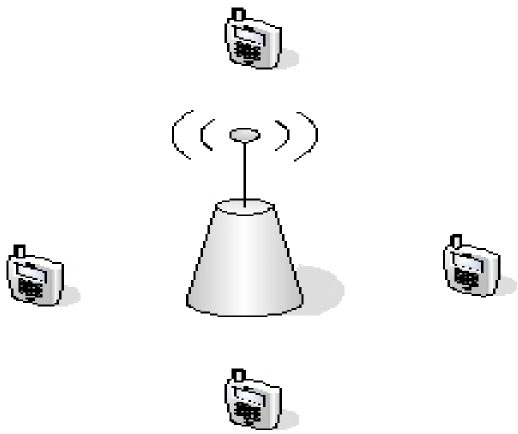


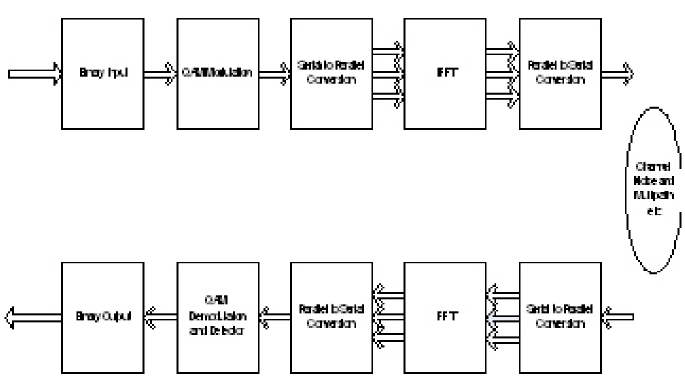
Fig.1. LTE downlink Transmission

Table. 1

Simulation Parameters

Parameters	Values
Sampling Rate 1/T	20MHz
Carrier Frequency fc	5.2GHz
FFT Size N	64
Useful Symbol Part Duration T_u	64T=3.2 µs
Cyclic Prefix Duration T_c	16T
Symbol Interval Ts=Tu+Tc	80T=4 µs
No. of Data subcarriers Nsd	48
No.of Pilot Subcarriers Nsp	4
Total Subcarriers Nsd+Nsp	52
NoiseVar	0.001
Rayleigh_var	0.5
Frame count	300
Symbol count	5

The block diagram of the LTE system for physical layer is



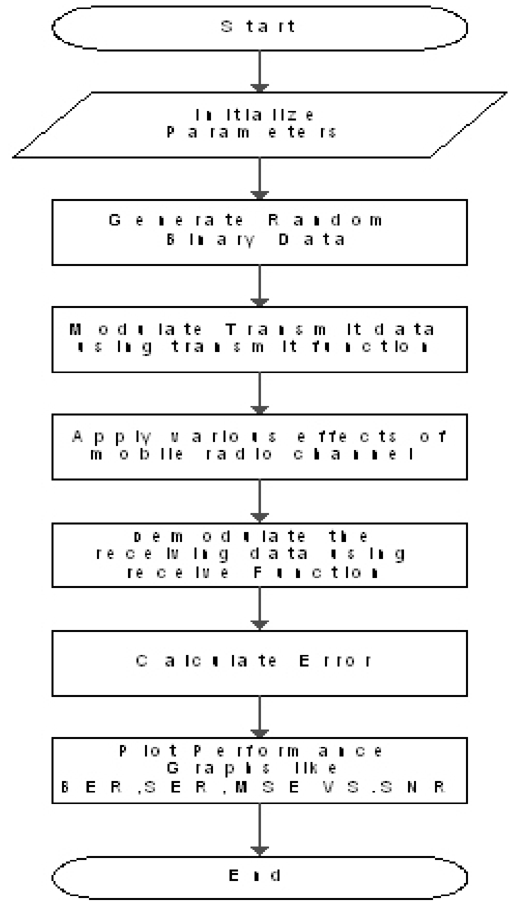


Fig.2. Flow Chart for main Programme

The flow chart for main programme which is written in MATLAB.

This main programme has two basic parts. One is LTE Transmitter and second is LTE Receiver.

The functionality of the LTE Transmitter and Receiver with main programme is represented in flowchart form as shown in figure.2, 3 and 4.The main programme has been written in MATLAB with functions of LTE transmitter and receiver. The simulation parameters which are used in main programme are given in table.1 shown above. The channel estimations have been measured between LTE transmitter and receiver which are the measures of BER, SER, MSE and Throughput vs. SNR.

The flow chart for the LTE transmitter and receiver are shown in figure.3 and 4 below. The codes for the functions of LTE transmitter, receiver and the main programme has been run over MATLAB and the results are measured with respect to SNR.

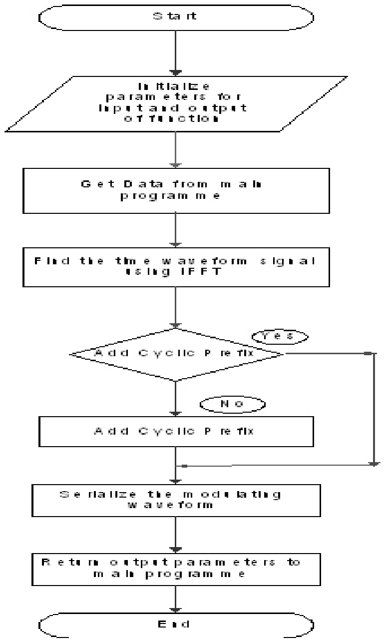


Fig.3. LTE Transmitter

This is the flow chart for the LTE transmitter is shown in figure.3. The main functions performed by the LTE transmitter are shown in blocks.

Similarly the flow chart for the LTE receiver is shown in figure.4

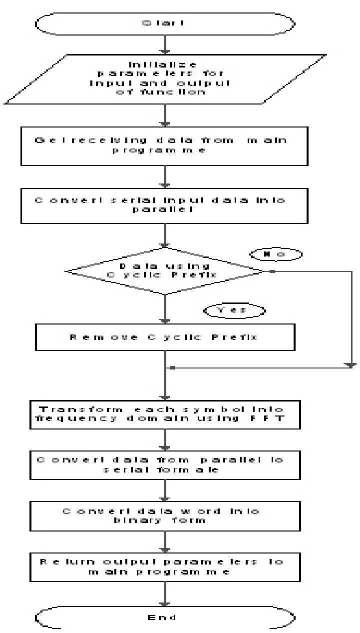


Fig.4. LTE Receiver

The performance of the LTE system is measured in the mobile channel which exits between the LTE transmitter and receiver. The performance measures are represented in the figures.5, 6, 7 and 8 below.

The average Mean Square Error (MSE) of the LTE system is compared with different values of SNR. The performance curve for this measure is shown in figure.5 below.

Fig.5. Average Mean Square Error for the Channel

The performance of the system can be evaluated by comparing the Symbol Error Rate (SER) for different values of SNR.

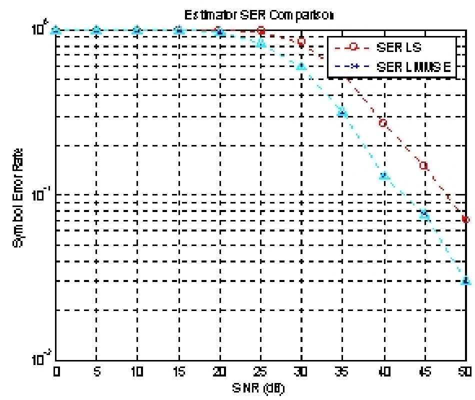


Fig 6. Symbol Error Rate Vs. SNR

The Bit Error Rate of the system can be evaluated with respect to Signalto-Noise Ratio (SNR). For very low signal-to-noise ratio value, the transmission may be suspended for a particular MT (outage) until its channel conditions improve.

In fig. 6. below the average BER results for different BER values are shown. Even for low values of SNR, average BER keep below the chosen target value.

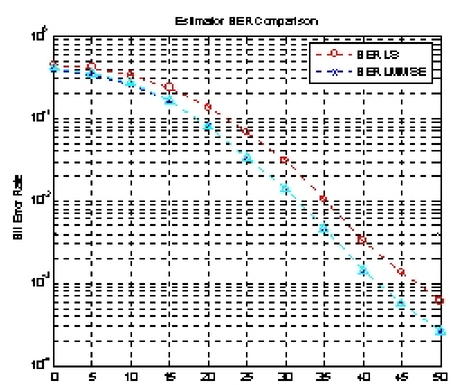


Fig.7. Bit Error Rate vs. SNR.

MIMO Throughput Results

Throughput CQI7, PedB, 5000 subframes, 3 retransmission

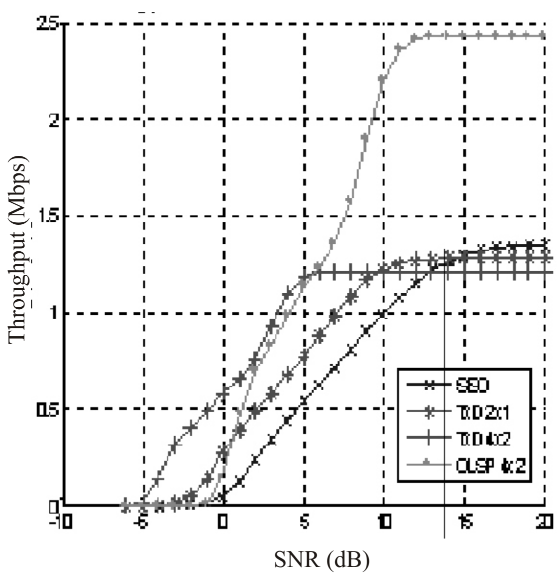


Fig.8. Throughput performance vs. SNR

The maximum throughput values are obtained by different MIMO schemes. It depends on the number of transmit antenna and on the number of data streams. If there are more transmit antennas for the transmission, then more pilot symbols are inserted in the OFDM frame which results the low maximum throughput. In case of Open Loop Spatial Multiplexing (OLSM), two spatially separated data streams are transmitted and that leading to twice the maximum throughput of the 4×2 T×D system. The MIMO throughputs are compared with respect to different signal to noise values in figure.8 above.

Conclusion

We have analyzed the performance of the new LTE cellular technology in this paper. The analysis has been done on the downlink transmission of physical layer of LTE which was simulated in MATLAB.The simulation results are the performance measures of the wireless channel which are measured in terms the Mean Square Error (MSE), Symbol Error Rate (SER), Bit Error Rate (BER) and maximum MIMO Throughput. The maximum throughputs are obtained in the downlink transmission by using Multi input and multi output (MIMO) scheme. The MIMO scheme shows that as we increase the number of transmit and receive antennas, then the overall throughput of the LTE system will also be increased.

The future work can be carried out in the uplink direction of the Physical layer of LTE which uses the SC-FDMA modulation technique in the uplink transmission. SC-FDMA is the advanced version of OFDM.

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Self Generation to Combat Power Crisis

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Abstract

Global energy game, appearing in the last 3 decades, has a particular context; while the resulting scenario in a country like Pakistan has taken its own shape. In Pakistan, the single largest emerging issue, has been the ghastly and acute crisis of power which unfortunately has been unintentionally or intentionally gravely mishandled. Alarm has been given on restoration of democracy, fighting terrorism, removing pollutions of all kinds, against which huge sums of foreign money has been spent, but very little has been said or done about the deplorable starving energy conditions in which people have been forced to get into. All governmental planning, mitigating actions, and privatization, have backfired. Technological solutions have not worked; because it is not the dearth of technology, it is the incompetence and wrongful doing on the part of earlier governments, which has brought people in the state in which they are now. The only way to reverse the power crisis is to let people produce their own power from whatever sources that are available to them, and to see that the money is not sucked out from them, and rather to divert some of it to improve the generating capacity of a community. It is in this direction, that the government effort and the foreign assistance programs should concentrate. Once the economic inflows and out flows from a system are controlled, the people will have improved generating capacities and they will themselves be able to take not only their own load but to support the government. Elimination of bottlenecks and putting people on self generation is a complex matter by itself. The quickest approach is building up systems for self generation through disbursement of technology and development of entrepreneurship. Participative mechanisms need to be formed in which an integral effort is done at the house holds, small communities, and industries while, need analyses, design development, development of tools and plant, management, micro-credits, and marketing functions are performed by professional bodies and volunteers in the respective fields after receiving suitable training. Although no efforts in the power field have been done on the above lines, positive efforts have been done on the above lines in the field of poverty alleviation. This paper describes the efforts being carried out by a number of persons including the author's team in this area.

The results of the pilot projects are very encouraging. The experience is expected to set the ball rolling. More people get into this kind of activity, better it will be and quicker will be the results. It is hoped that, soon after, a self growth path will be picked up by many, and expanded to national level. Ultimately, it is hoped that the back lash of poverty that reflects badly on the well being of people ends.

Deterioration Of Power Conditions

Pakistan's current total installed capacity of WAPDA and KESC amounts to 19,500 megawatts. Almost two third of this power comes from thermal power plants (fossil fuels), one third is generated by water and about 2% comes from nuclear power plants.

The demand for electricity in Pakistan during the winter months actually goes down and this winter has not been an exception. Throughout the month of December, the electricity consumption in Pakistan hovered around 11,000 MW, down from the peak levels of 17,500 MW seen in summer. This demand was well within the installed capacity of WAPDA & KESC yet they were only generating a meager one third (6500MW) of their maximum capacity during this period leaving a huge gap between supply and demand.

From the failure to build new dams and the Government's inability to add even a single megawatt of new power to the grid during 9 years of its rule, it seems that the present crisis is a result of bad management and the lack of foresight.

The power crisis that the nation is facing is the cumulative effect of incompetence, and greed, on a massive scale. Since 1990, all the successive governments stressed the necessity for speed, so that the planning and execution of new projects should be completed before the shortages took on a pandemic form. Entrepreneurs were lined up to fund the start-ups and they came forward in droves. Deals were struck, kickbacks were negotiated and added to the project cost to be repaid along with the capital cost of the machinery. By none other than the consumers paid for the crafty work.

The oil companies have played a role to keep their considerable interests protected, by ensuring that the other options to generation of power be put on the back burner, then never to see the light of day.

The KESC and PEPCO owe more than Rs. 10b to the independent power producers (IPP) and paying them will help bring them into full operation and ease the crisis at least partially.

Pakistan Electric Power Company (PEPCO) blames independent power producers (IPPs) for the electricity crisis, as they have been able to give PEPCO only 3,800 W on average out of 5,800 MW of confirmed capacity. Most of the IPPs are running fuel stocks below the required minimum of 21 days. IPPs complain that they are not being paid on time by PEPCO.

More strange incidences have been happening. On September 15, 2008, the Unit no. 5 of the Bin Qasim Power Plant, which normally generates 1185 megawatts tripped after developing some technical fault. The Plant could churn out only 560 megawatts with the suspension of electricity to the metropolis of Karachi.

The Korangi Thermal Power Plant which supplies 180 megawatts. Due to some unknown reasons dropped its production to 50 megawatts rather than its usual capacity of 180 megawatts.

Power transmission from Tarbela, Ghazi Barotha broke down on Sep 24, 2008, which caused black out to several cities and districts following another major power breakdown struck across Pakistan due to a fault in the national electricity transmission system.

There is no alternative but to resort to hours of load shedding. In June 2007, the power cuts in Pakistan lasted no more than 3 or 4 hours a day. This year, in extremely hot weather, Pakistanis have to endure without electricity for 8 to 10 hours a day. Industrial production is suffering, exports are down, jobs are being lost, and the national economy is in a downward spiral. By all indications, the power crisis in Pakistan is getting worse than ever.

If almost a third of the people of the world will live in power less conditions 30 years from now as the latest report of the UN Habitat projects, (1), how many more in Pakistan are already languishing in such horrid living conditions which are springing up all over the country?

Pakistan, which already faces this problem in a large dimension have to stand up and think.

Alternative Sources Of Power

Large hydro power generation projects involve a number of social, political and technical issues. Despite the government's intensive campaign, it has failed to remove the fears of Sindh and NWFP on the issue of the Kalabagh Dam. Also, the construction of barrages and dams upstream on Indus has degraded the Indus delta. The promises of cheap hydro energy from large dams, if analyzed from a sustainable development prism, are not reliable because of two reasons; first, there is a vocal demand to include the social displacement and environmental degradation costs in the up-front capital costs of such projects.

Financing of such mega projects remains the most important aspect of this problem. Funding from international donors for such a project is difficult to receive, considering their commitment to facilitate investments in private thermal based power plants.

Second, even if the government arranges funding for such projects, the outlays involved in resettlement compensations are huge. For example, the government intends to spend Rs2.025 billion on the resettlement issues of the Kalabagh Dam by constructing 20 model and 27 extended villages.

Wind Source:

Near Islamabad, the wind speed is anywhere from 6.2 to 7.4 meters per second, while near Karachi, the range is between 6.2 and 6.9. There also exists a corridor between Gharo and Keti Bandar that carries regular wind of sufficient speed. The Alternative Energy Development Board (AEDB) was created in 2006 to pursue renewable energy. In Mirpur Sakro, 85 micro turbines have been installed to power 356 homes. In Kund Malir, 40 turbines have been installed, which power 111 homes. AEDB has also issued a letter of intent Makwind Power Private Ltd for the setting up of 50MW wind farm at Nooriabad in Sindh. An Indian company, Suzlon, has developed wind turbines, those start to turn at a speed as low as 3 meters per second. India now has the world's fourth largest number of wind turbines that have a capacity of 7,000 MW. The cost of wind power in India, however is between 2 and 2.5 cents per kilowatt hour while in Pakistan, the cost is 7 cents.

Solar Power:

Pakistan is an exceptionally sunny country. Impressed by advantages of solar power, National Institute of Silicon Technology (NIST), the Pakistan Council of Appropriate Technology (PCAT) and the Solar Energy Research Centre (SERC) and the Pakistan Council of Scientific and Industrial Research (PCSIR) were created to develop affordable means of solar power. Two decades after spending millions of rupees on the establishment, capital and operational cost on these institutes, NIST and the PCAT have been wound up and a new organization namely the Pakistan Council for Renewable Energy Technology (PCRET) has been established to further spend capital resources on failed and uncompleted projects of NIST and PACT. The directorate of renewable energy of the Ministry of Petroleum and Natural Resources has been closed after the failure of the project on solarization of some villages.

Small Hydro Electric Power:

However, small hydro power plants have emerged as a desirable option, especially for hilly terrains where natural and manageable waterfalls are abundantly available. Being environmentally benign and having a small gestation period, small hydro resources receive worldwide attention both in developed and developing countries to augment energy generation. Small hydro plants offer a wide range of benefits, especially for rural areas. Development of small hydro power plants (SHP) around the world has increased substantially. There are over 420 small projects producing 1423 MW in India

Coal Power:

Pakistan has the fifth largest coal deposits in the world. The negative environmental effects of coal burning can be mitigated by making use of the latest clean coal technologies that limit noxious gas exhaust into the atmosphere.

Traditional Sources:

Traditional energy sources are firewood, animal dung, and bagasse (residue left-over from crushed sugar-cane) still make up more than half of all energy consumed in the rural areas.

Indian Model For Rural Power

India has embarked upon a Clean Development Mechanism (CDM) with a target to supply the 87,000 non-electrified rural villages in the first phase.

Participatory energy planning:

A participatory rural energy project involves project stakeholders individuals or organizations who have an interest in developing an energy system or are significantly affected by its impacts in all stages of the project. Communities play a key role in selecting, purchasing, operating and maintaining their own system. Communities have to attach energy system with greater goals of income generation, employment or basic infrastructure.

Decentralized energy planning:

Villages rely on energy sources that are locally available, rather than receiving electricity from a remote power plant. The use of local energy sources facilitates reliance on traditional ecological knowledge and reinforces the capacity of communities to manage their own energy supply.

The incumbent rural energy framework is centered on biomass, which is inherently decentralized in nature. Extending this paradigm from its current focus of household biomass combustion to an integrated energy supply model that includes community electricity generation would improve the quality of life of rural people and be more economical than extending the central electricity grid.

Nature of Projects: Six of these projects fit the rural energy model described above, as they are based on renewable energy technologies and could be implemented in a decentralized fashion using participatory methods:

* Small hydro power generation
* Biomass power generation
* Solar photovoltaic cells
* Improved cookstoves
* Residential solar cookers
* Residential biogas plants

The "ecosystems approach" has been adopted for rural energy promotes ecological conservation and rural development through the appropriate management of environmental and social resources. This methodology is based on a decentralized biomass model and incorporates local knowledge and conditions into the project design.

Community Power Generation Experiences In Pakistan

In fact, Pakistan Council of Renewable Energy Technologies (PCRET) has implemented 290 micro-hydro power (MHP) schemes in FATA and the northern areas with a total capacity of 3.5MW, ranging from 3-50kW per plant, with the participation of local community. All of these plants are run-of-river type in the low (four meter) to medium (30 meter) head range.

Similarly, Aga Khan Rural Support Programme (AKRSP) has constructed 171 micro-hydel units providing electricity to around 17,000 households in the remote and isolated region of northern Pakistan, and currently provides 11,000 households with electricity in very remote locations.

Once the plant is installed, the local community takes the responsibility of operating it. These plants provide electricity mainly for domestic purposes. Local people have installed agro processing plants for flour grinding, rice husking, lathe, in the power house. Such units are run during the day time, directly from the turbine shaft. The electricity produced through micro hydropower in the country is in the range of 5-50 kW.

A major advantage of micro hydro is that it can be built locally at a considerably less cost. For instance, imported turbine sets generating up to 50 kW cost approximately Rs30,000-60,000 per kW, while the local manufacturers located in Taxila, Gujranwala, Lahore, Karachi offer facilities for turbine manufacturing at Rs10,000-15,000 per kW, with marginally reduced turbine efficiencies. The cross flow turbine used by PCRET and AKRSP is manufactured in local workshops.

Examples Of What Can Be Produced Within The Community

Micro Hydro power systems:

Not everyone is lucky enough to have a source of running water near their homes. But for those with river-side homes or live-on boats, small water generators (micro-hydro turbines) are the most reliable source of renewable energy available. One relatively small water turbine will produce power non-stop, as long as running water is available, no matter what the weather.

Fig.-1: Immiscible Stream Power Generator

Micro Wind Power Generator:

A robust micro wind power generator is a tower mounted unit. It has low maintenance, and has automatic operation in adverse weather conditions. It can be favorably manufactured by many homeowners and professionals. It is particularly suitable for villages and remote stations. With only a few moving parts and heavy duty construction, it has no scheduled maintenance. It can either be battery charging and grid-connected. It is normally rated at 10 kW. The turbine is aligned into the wind by a tail assembly. The tail boom and and integrated rotor/alternator assembly attach to the mainframe assembly, which incorporates the yaw-axis slip-rings and the tower interface. The geometry of the mainframe creates the passive high wind speed protection. The mainframe offsets the rotor and yaw axes such that rotor thrust produces a furling moment about the yaw-axis. The weight and inclined pivot of the hinged tail provides a preset resistance to the rotor furling moment. Over speed control is initiated at a limited speed when rotor thrust overcomes the tail resistance and restoration is caused by gravity as the wind speed subsides. There is no shut-down wind speed. The turbine can be manually shut-down using a furling winch installed at the base of the tower.

Battery charging can be supplied with outputs of 48, 120 or 240 VDC. They are well suited for large rural homes, remote villages and facilities, eco-tourism resorts, and larger telecommunications sites.

Connection to the grid, can provide most of the electricity for an average total electric home at moderate wind sites. An inverter is added for grid connection.

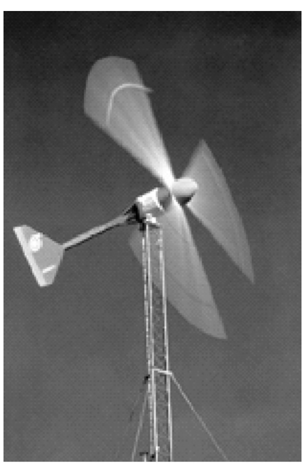

Fig.-2: Wind Power Generator

Solar Photovoltaic Cell Modules:

Electric photovoltaic modules are designed for both commercial and domestic applications and are suitable for grid connections. Polycrystalline PV modules can give desirably high power output. Cell strings are protected by sheets of ethylene vinyl acetate (EVA) and laminated between a weatherproof backing film and a highly transmittive, highly impact resistant, tempered glass and light can be effectively converted to electricity by using an anti-reflection coating.

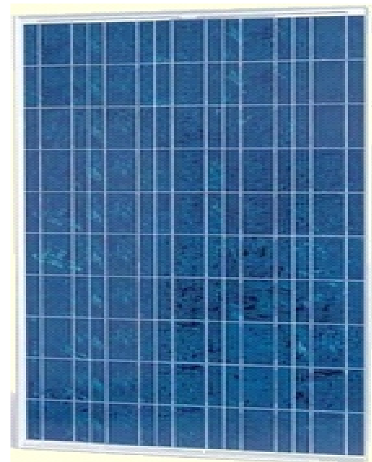

Fig.-3: Photovoltaic Cells Module

Parabolic Solar Water Heater:

A simple or articulated parabolic water heater can raise sufficient temperatures that can greatly reduce the steam turbine effort. it can be assembled only with nut-bolts and other activities like forming a parabola at the site. The efficiency could be improved by 'enclosing' the boiler vessels. It can non-tracking which means that the geometry is such that it may not require constant viewing towards sun.

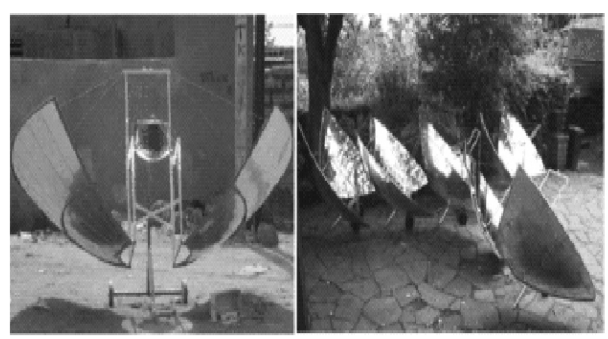

Fig.-4,5: Parabolic Solar Water Heaters

Garbage Power

Plasma arc garbage plants can burn any waste with minimal or no pretreatment; and they produce a stable waste form. The arc melter uses carbon electrodes to strike an arc in a bath of molten slag. The consumable carbon electrodes are continuously inserted into the chamber, eliminating the need to shut down for electrode replacement or maintenance. The high temperatures produced by the arc used to run steam turbines. Power plants run on garbage are functioning in a number of countries, such as Japan and China

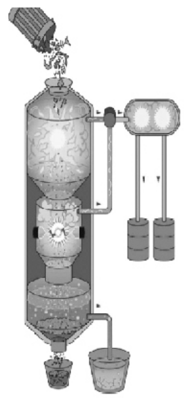

Fig.-6: Garbage Power Plant

Participatory Self Generating System

Objective

The only way to provide power and improve living conditions on a mass scale, is to look at a locality as an economic system and to see what are the inflows and the out flows, and to divert some of them to be allocated to power generation there. This can be done only when their stocks are enhanced, and there is surplus to spend.

The power generation is not stand alone. It has to be integrated with the overall enhancement of the capital circulating within the community as described on Fig: 7, generating capacities of small businesses, workshops and households in poor areas through technology additions and entrepreneurship development, by establishing and running participative cell system.

Cell System

Cell System is a system of independently working individuals, who are interlinked with each other, through specific give and take mechanisms, and are geared towards the common broad objective, as regulated by a central coordinated unit.

Central Coordination Unit

Central Coordination Unit is a group of highly devoted resource persons whose function is to:

(i) train the trainers,
(ii) coordinate the activity,
(iii) to ensure quality, and
(iv) to disburse the Central Fund.

Individual Cell Units

1. Design Developers:

These are engineers and technologists, who develop plants and technology.

2. Factories:

The generators, gadgets, tools, and plants, will be manufactured by the factories, who agree to participate for these purposes.

3. Trainers:

The professional bodies raise trainers who go around in the communities to train people.

4. Creditors:

Credit is arranged from the creditors, so that the communities can get the machines, gadgets, tools, and plants made, as well obtain the raw materials and working capital.

5. Marketers:

The Marketers identify appropriate power generators, and market them.

Conclusion

A severe issue, in Pakistan today are the ghastly devastating power conditions which unfortunately has been totally mismanaged. The only way to come out of this difficult situation is to resort to self generation within communities integrated with positive steps towards building of the earning capacities of the people. Participative mechanisms need to be formed in which the power production is done at the community level, with need marketing, design development, development of tools and plant, production management, micro-credits, and marketing functions. The experiences of the exercises conducted in limited areas are very encouraging. The effort is expected to set the ball rolling. More people get into this kind of activity, better it will be and quicker will be the results.

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Quotation

* The greater our knowledge increases, the greater our ignorance unfolds.

John F. Kennedy

* The acquisition of knowledge is the mission of research, the transmission of knowledge is the mission of teaching, and the application of knowledge is the mission of public service.

James A. Perkins

*. The greatest obstacle to discovery is not ignorance - it is the illusion of knowledge.

Daniel J. Boorstin

* Knowing others is wisdom. Knowing the self is enlightenment.

Lao-tzsu

* Knowledge which is obtained under compulsion obtains no hold on the mind.

Plato

*. The great end of life is not knowledge but action.

Thomas Henry Huxley

*. Youth longs and manhood strive, but age remembers.

Oliver Wendell Holmes, Sr.

*. The true art of memory is the art of attention.

Samuel Johnson

* A retentive may be a good thing, but the ability to forget is the true token of greatness.

Elbert Hubbard

*. The only place where success comes before work is in a dictionary.

Vidal Sassoon

*. Behind every successful man there re a lot of unsuccessful years.

Bob Brown

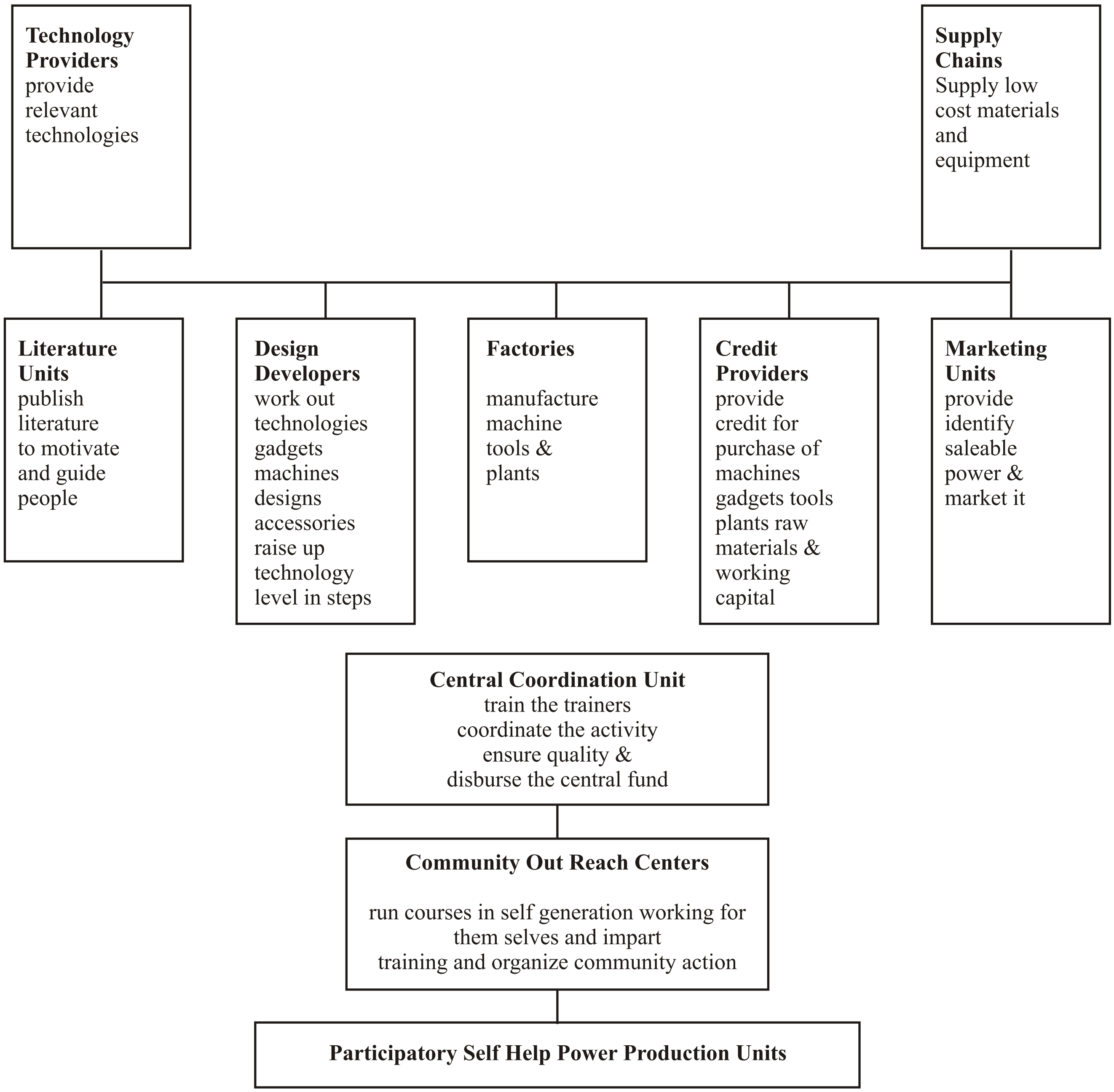
* Nothing fails like success because we don't learn from it. We learn only from failure.

Kenneth Boulding

* All you need in life is ignorance and confidence, and then success is sure.

Mark Twain

Fig. 7: Networking and Inter relations



Development of CsdS/CdTe Thin films by Low Cost Techniques for Photovoltaic Applications

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Abstract

The CdS/CdTe solar cells can be easily fabricated in the form of thin films. Solar cell studies based on CdS/CdTe fabrications has been started for several years and in recent days, it has got much potential to replace the conventional silicon based technology. The CdS/CdTe solar panels are more attractive these days due to low cost and simpler ways of fabrication. CdS/CdTe solar cells have got record efficiency of 16.5% at laboratory scale. Also, the commercial solar panels following this technique claim 30 years life of a solar cell module.

In this paper, we review the processes need to produce the high efficiency CdS/CdTe solar cells from the point of view of thin film techniques. Further more, it is illustrated how to develop the modules at larger scale in industry.

Introduction

During the last 15-20 years the photovoltaic world has been enriched with some interesting materials other than crystalline solar cell (Silicon technology), such as CdTe and $CuInSe_2$. Both these materials are considered very suitable for the fabrication of solar cells because of their direct band gap. As a consequence of the direct energy gap, the absorption edge is very sharp and thus, more than 90% of the incident light is absorbed in a few micrometers of the material. The maximum photo current available from a CdTe cell under the standard global spectrum normalized to100 mW/cm^2 is 30.5 mA/cm^2 and the theoretical maximum efficiency of CdTe is over 27%. Recently an energy conversion efficiency record for CdTe of 16.5% has been reported [1]. This record, despite its achievement on a laboratory scale, demonstrates that CdTe thin film technology has arrived at a level comparable with the more sophisticated technologies typical of single crystal materials. One of the best characteristics of this semiconductor is that it is possible to fabricate a complete photovoltaic device using only thin film technology. This extraordinary fact has been well known ever since 1972 when Bonnet and Rabenhorst [2] published an interesting paper on CdTe/CdS thin film solar cells reporting an efficiency of 6%. There followed a period during which several research groups tried to develop a solar cell fabrication process based on related thin film deposition techniques. However, it was only in the 1980s before the 10% efficiency value was overcome by Tyan and Albuerne [3]. Subsequently an efficiency of 15.8% was reached by Ferekides et al. [4] and most recently a research group of NREL reported a record efficiency of 16.5% [1]. An interesting fact has been reported in recent works that CdTe/CdS solar cells fabricated using thin film technology exhibit higher efficiencies than those fabricated from single crystal materials. In fact, solar cells with an efficiency around 10% or higher have been made as hetero-junctions, homo junctions, buried homo junctions and MIS junctions, using CdTe single crystal.

Type of cells	Open-circuit voltage Voc (mV)	Short-circuit current Jsc (mA/cm^2)	Energy Conversion efficiency (%)	Ref.
CdTe single crystal				
Buried homojunction:n-ITO/p-CdTe	890	20[a]	13.4	[5]
Heterojunction: n-ZnO/p-CdTe	540	19.5[a]	8.8	[6]
CdTe homojunction: p-CdTe by CSVT on n-CdTe single crystal	820	21[a]	10.7	[7]
Thin films				
All thin film CdTe solar cell			6	[2]
(CdS and CdTe by low temperature CSS)	750	17[b]	10.5	[3]
(CdS by CBD and CdTe by high temp. CSS)	843	25.1[a]	15.8	[4]
(CdS by CBD and CdTe by low temp. CSS)	845	25.88[a]	16.5	[1]

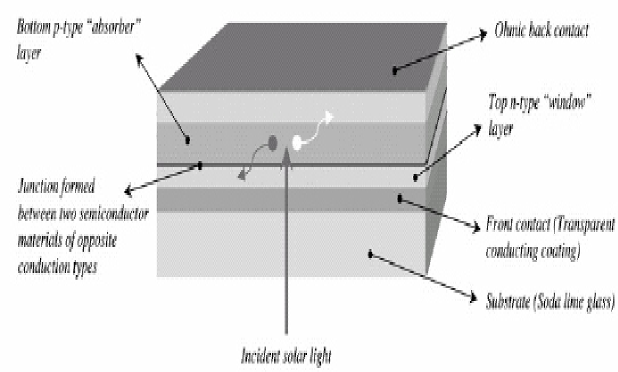
Table 1: Representative data for single crystal and all thin film p-CdTe solar cells

a) Under simulated AM 1.5 solar illumination at 100 mW/cm^2.

b) Under simulated AM 2 solar illumination at 75 mW/cm^2.

All photovoltaic devices involving CdTe as an absorber material contain a highly transparent and n-conducting partner, which promotes the creation of a depleted region in the p-conducting CdTe film. In highly efficient CdTe based solar cells this partner is CdS and, despite the lattice mismatch, which is 9.7%, the interface shows a good behavior without the typical recombination losses associated with junction interface states [8]. The CdS, with a forbidden energy gap of 2.42 eV, acts as a filter for solar light having a cut off at 514 nm; for this reason this device loses part of the solar spectrum which corresponds to a theoretical loss in the short-circuit current of about 5 mA/cm^2. The electrical resistance of the CdS film may become an important factor that affects the whole solar cell behavior. To avoid this factor CdS film thickness is usually taken very small. The minimized thickness also improves transmission of light to the CdTe layer. These CdS films are suitable for solar cell purposes because they increase their conductivity under illumination.

In this paper we want to review the typical thin film techniques that are able to produce highly efficient CdTe/CdS solar cells and especially those that are ready for industrial production. We have also added our practical work in this regard at numerous occasions at this paper. In particular we want to show an all in-line process, starting from a laboratory scale and based on classical thin film technology, in order to demonstrate that it is possible to produce large area photovoltaic modules with high throughput. The major ingredient layers of a typical thin film technology solar cell are shown in the figure below:



The CdS/CdTe Solar Cell:

The schematic diagram of modern thin Film Solar cell has been shown in figure above. The brief description of the layers is given below. Afterward, we will discuss the methods and techniques used for fabrications of these films.

The substrate can be soda-lime glass (SLG, the common window glass) or special alkali free glass. At laboratory level, the microscopic glass slides can be taken as potential candidate at laboratory scale.

The front-contact layer is commonly made of a TCO such as ITO (indium tin oxide), IFO (fluorine doped indium oxide) or FTO (fluorine doped tin oxide). On top of this electrical conductive layer are often deposited a few nanometers (50-200 nm) of a buffer layer such as pure TO (tin oxide), ZnO (zinc oxide) or Ga_2O_3 (gallium oxide) which has the role of a shield against the probable diffusion of Na and K atoms.

The window layer, that is the CdS film, represents the n-type part of the junction. It can be deposited in a number of ways.

The p-type CdTe layer. In efficient CdTe/CdS solar cells, CSS (Close-Spaced Sublimation) is the most popular technique used to deposit 4-7 mm thick CdTe films. The CSS technology is also very reliable to be used at industrial level.

The back contact layer to get the best electric power from a solar module. So far the best-suited back-contact has so far been made by depositing 100 nm of Sb_2Te_3 by sputtering on top of the CdTe layer in order to obtain a stable and ohmic contact.

Let us now discuss various low cost methods and techniques involved in the fabrication of these layers to be implemented at laboratory level, which are used to develop low cost CdS/CdTe solar cell.

Transparent conducting oxides (TCOs):

In recent years there has been a great interest in metallic oxides thin films due to their many industrial applications [9-10]. Thin films of these materials (TCOs) are produced by several deposition techniques. The most studied TCOs are: SnO_2: F (FTO), ZnO: Al (AZO), In_2O_3: Sn (ITO), and Cd_2SnO_4 (CTO)[11]. These metallic oxides exhibit very good optical transparency nearly or more than 90% for visible light and near infrared radiation and very high n-type conductivity. The high transparency and also the high electrical conductivity make the TCOs suitable for a great variety of applications. In fact they are used in optoelectronic devices and as transparent electrode in photovoltaic modules. Also they have been employed in glass coatings, for example as transparent heating elements for planes and car windows.

Because of their high reflectivity in the IR part of the spectrum they could also be used as transparent heat-mirror coatings for buildings, cars and energy saving light bulbs. Since it is not possible to obtain both high electrical conductivity and optical transparency in any intrinsic material, one way to reach this aim is to create electron degeneracy in a wide band-gap oxide. This could be made in two different ways:

1. Introducing donor elements into the oxide matrix.
2. Exploiting deviation from correct stichiometry by, for example, using structural defects and/or oxygen vacancies.

SnO_2 (TO) is the first transparent oxide to have received relevant commercialization. Nowadays, TO films are used in products like "low-emissive" windows, photovoltaic modules, flat-panel displays, heated windows, etc.

Some useful properties of the CVD TO films are as follows:

High transparency in the visible part of the light spectrum (more than 90%);

High reflectivity for infrared light;

Low electrical resistivity (on the order of 10^{-4} Ù cm for fluorine doped TO);

Good environmental steadiness;

High mechanical hardness.

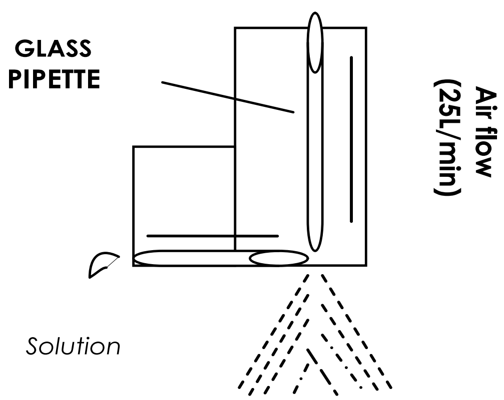
TCO layer has been fabricated in a number of ways and techniques including The In_2O_3 (IO) family, the tin doped In_2O_3 (ITO) films [12], Germanium doped indium oxide (IGO) films, and Fluorine doped indium oxide (IFO) films, Fluorine doped zinc oxide (FZO)[26][27], Zinc and Cadmium Stannate (Zn_2SnO_4 -Cd_2SnO_4). A lot of methods have been developed such as chemical spray pyrolysis (CSP), [1], sputtering [2], metal organic chemical vapor deposition (MOCVD), RS-MBE [4 - 7] and Sol Gel process [15]. Her we are discussing some common low cost methods.

F: SnO_2 by sol- gel technique:

Sol Gel technique involves preparation of a sol-gel for a particular material with some organic solvent. Then the substrate is dipped and heat-treated to get the desired results. In our work, we made 0.2 M solution of $SnCl_2$ with some organic solvent with doping of fluorine at the ratio of 1: 15 Heated it at 363K with constant stirring until a gel is formed. The substrate after dipping was dried in oven at 373 K and then annealed at 673 K. The step may be carried out many times until get the required results. The average resistivity obtained by this method approaches 1 x 10^{-2} Ù cm.

F: SnO_2 by spray pyrolysis technique:

Instead of conventional nozzle, a more convenient simple method for spraying was adopted as shown in figure.



In this technique, we made 0.2 M solution of $SnCl_2$ with an organic solvent. Add few amount of Ammonium Flouride solution in it with ratio of 1: 15 as a doping agent. The substrate is preheated at 723 K so that the solution decomposes and form oxide layer on the substrate. The TCO layer obtained in this method needs not to be annealed further.

The CdS Layer:

The CdS film in the CdTe/CdS solar cell is the so-called window layer. Since it is n-type it enables the formation of a pen junction with p-type CdTe. With an energy gap of 2.42 eV, CdS is transparent in the visible part of the solar light spectrum and therefore the solar light can penetrate into the CdTe layer thus giving rise to the photovoltaic effect.

Since the p-n junction formed between n-type CdS and p-type CdTe is strongly dependent on a proper interaction between these two layers, the deposition technique used to prepare these materials becomes very important. In particular for CdS the most suitable deposition techniques are the following: R.F. Sputtering [13], Close-Spaced Sublimation (CSS) [14], High-Vacuum Thermal Evaporation (HVTE) [16,17] and Chemical Bath Deposition (CBD) [18,19]. Although the highest energy conversion efficiency was obtained by using a CdS layer prepared by CBD, it is normally preferred to use the sputtering or CSS deposition method since CBD is not so suitable for large-scale production.

In Cds fabrications, one should compromise on thickness to reveal good transmission without leaving a pinhole. A suitable CdS layer should have transmission in range of 70 %. Also the minimized thickness of CdS reveals loss of conductivity through TCO layer.

CdS Layer by Chemical bath Deposition (CBD):

In CBD, CdS films can be prepared by exploiting the decomposition of thiourea in an alkaline solution of cadmium salts, following the reaction:

$$Cd(NH_3)_4^{2+} + SC(NH_2)_2 + 2OH^- \rightarrow CdS + CH_2N_2 + 4NH_3 + 2H_2O$$

Normally $CdCl_2$ is used with an Ammonia salt. In the process, we take $CdCl_2$, SC $(NH_2)_2$, KOH in amount 0.2 M, 0.2 M, 0.04 M respectively in water solution. Then, clean dry substrates are suspended in the bath at temperature reaching to 80 °C. The solution or substrate is moved uniformly during the reaction. Then, the chemical reaction undergoes following stages:

Nucleation period:

First of all the chemical reactions in the bath are completed and an initial monolayer of the metal chalcogenide is formed on the surface of the substrate (the CBD technique requires extremely careful substrate cleaning).

Growth phase:

When the surface of the substrate is entirely covered by the initial monolayer, this can act as a catalytic surface for the condensation of metal and of chalcogenide ions resulting in film growth.

Terminal phase:

The chemical reactions change during growth and, as a consequence, the deposition rate changes. In fact, the growth rate assumes a maximum value after a certain time depending on the solution parameters and finally, when the ions species diminish, it achieves a terminal phase at which the film stops growing.

The layers formed in this manner are not having good adhesive properties until they are annealed at 773 K. For better performance of p-n junction, CdS layers are annealed after $CdCl_2$ treatment. In fact, the energy gap of 2.42 eV is observed only for films annealed at a temperature above 773 K for 1 h.

CdS by Spray Pyrolysis Technique:

CdS can also be deposited by using spray pyrolysis method as explained earlier in schematic diagram. For CdS we take equal molar solutions of $CdCl_2$ and Thiourea and spray them at constant rate for a particular time. The substrate is heated in this case at 750 K. The layer formed in this way has very strong adhesion. Further, they need not to be annealed as already prepared at high temperature.

The CdTe Layer:

All photovoltaic devices involving CdTe as an absorber material contain a highly transparent and n-conducting partner, which promotes the creation of a depleted region in the p-conducting CdTe film. In highly efficient CdTe based solar cells this partner is CdS and, despite the lattice mismatch, which is 9.7%, the interface shows a good behavior without the typical recombination losses associated with junction interface states [8]. The CdS, with a forbidden energy gap of 2.42 eV, acts as a filter for solar light having a cut off at 514 nm; for this reason this device loses part of the solar spectrum which corresponds to a theoretical loss in the short-circuit current of about 5 mA/cm^2. The electrical resistance of the CdS film may become an important factor that affects the whole solar cell behavior. Generally the thickness of the CdS film is minimized having in mind the need to preserve the best properties of the cell such as the open-circuit voltage. CdTe exhibits a forbidden gap of 1.45 eV very close to the maximum for solar energy conversion. Also its gap is direct and its absorption coefficient is in the range of 10^4 to 10^5 cm^{-1} for photon energies larger than the forbidden gap. This means that only a few micrometers of material are enough to absorb all the light. A theoretical maximum efficiency over 27% and a practical efficiency of 18.5% could be expected for this material.

The CdTe fabrications have been reported in the number of ways. However, for the consequence of low cost techniques, we used screen-printing and CSS (close space sublimation) techniques.

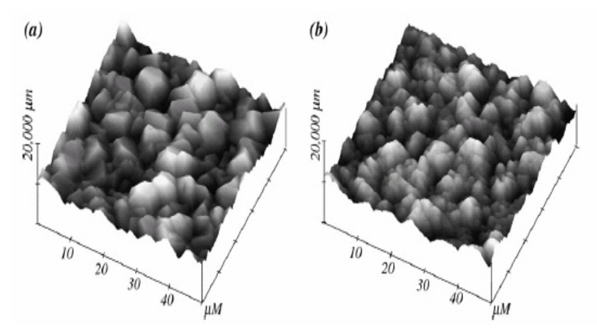
CdTe by screen-printing:

Screen-printing is simplest of all the techniques. It is same technique, which is commercially used for printing of wedding cards etc. For this technique, we need very fine ground CdTe powder. Make a paste of CdTe with polyglycol or some other binder. It is then screened out from some very fine mesh (e.g. 400 mesh) SS net to obtain a relatively thick layer. The layer is then sintered at 450 °C and then annealed at 750 °C to get proper layer with good adhesion and make a junction with CdS. In comparison with other technologies, screen-printing normally leads to thick layers (10 - 20 mm instead to some micrometers).

CdTe by CSS (Close space sublimation):

Close space sublimation is slightly expensive and most sophisticated technique as compared to other low cost techniques discussed so far. The deposition is carried out at high temperature in an inert or reactive gas at a pressure in the range 1-100 mbar. This type of deposition is possible because CdTe dissociates into its elements ($2CdTe(s)2Cd(g) + Te_2$ (g)), which can recombine on the substrate to form the CdTe film. The CdTe deposition can be carried out with the use of a sintered sputtering-like target in a graphite crucible. This target is disk shaped 3.0 in diameter and is manufactured using 99.9999% purity CdTe powder that is placed in a graphite crucible inside an oven. Then under a 10 bar N_2 pressure, the temperature is raised up to 1200 K for few minutes and then slowly lowered to room temperature. The distance between source and substrate is typically 2-7 mm and the temperature of source and substrate is 750 K and 850 K, respectively. With these parameters a 6 mm thick CdTe film can be deposited in 2 min [20]

The addition of few amount of oxygen to the system can reduce the particle size of the deposited film. The AFM images of the deposited film are shown in the figure below:



(Atomic Force Microscope) picture of two CdTe layers deposited at 500 _C substrate temperature by CSS technique with 650 _C source temperature. (a) Ambient: pure Ar; total pressure: 1 mbar; average grain sizez10 mm. (b) Ambient: Ar þ O2; total pressure: 1 mbar (Ar) þ 1 mbar (O2); average grain sizez2e3 mm.

CdTe films grown by CSS enhanced their crystalline and electro-optical quality if the deposition is carried out in Ar + O_2 atmosphere. The effect of oxygen on the CdTe growth is very strong: it increases the CdTe conductivity and reduces the grain size making the film more compact allowing the use of thinner films about 4 - 6 mm thick.

By varying the oxygen percentage from 1 to 100% with respect to the total Ar + O_2 atmosphere it is possible to adjust the interaction between the CdS surface and the arriving Cd and Te atoms at the beginning of the deposition. In other words, independent of the total pressure, in the presence of oxygen there is a change in the equilibrium between the CdTe sticking coefficient and the surface diffusion coefficient. Oxygen makes more stable the presence of Cd and Te atoms on the CdS surface due to its tendency to form compounds with both Cd and Te.

The Heat Treatment:

There are different treatments to improve the efficiency of solar cell. The most common is $CdCl_2$ treatment This treatment is generally carried out by depositing a $CdCl_2$ film on top of CdTe by evaporation or by dipping the CdTe layer in a solution of $CdCl_2$ methanol and with a subsequent annealing at 400 °C in air or in an inert gas such as Ar [21, 22]. The presence of Cl_2 could favor the crystalline growth of CdTe by means of local vapor phase transport. In this way the small grains disappear and the CdS/CdTe interface is reorganized. This method is very effective in producing high efficiency cells. It avoids the use of $CdCl_2$ that could be dangerous and instead it uses a gas that is stable, inert and non-toxic at room temperature. Besides it eliminates the $CdCl_2$ evaporation step and, as a consequence, it is much more suitable for an industrial production. This process has been patented [23].

The Back Contact Problem:

It is one of the major issues to get maximum output of a p-n junction. Therefore, a proper back contact with maximum efficiency should be achieved. Most researchers make the contact on p-type CdTe films by using Cu-containing compounds, such as a Cu-Au alloy, Cu_2Te, ZnTe: Cu or Cu_2S. It is believed that Cu is necessary to make an ohmic contact on p-type CdTe. In fact, copper, by diffusing into CdTe lowers its resistivity and for a while it gives a higher solar cell performance. Moreover, CdS/CdTe solar cells made with contacts not containing Cu behave as if they have a high series resistance. Before depositing Cu, an etching in Br-methanol or in a mixture of HNO_3/HPO_3 acids is carried out in order to enrich the CdTe surface with Te.

In fact, it was verified that Sb_2Te_3 makes an ohmic contact with p-type CdTe thin films and was also found out that Sb_2Te_3 makes an ohmic contact on a p-type CdTe single crystal whose resistivity was of the order of 10^5 Ù cm [24]. Actually the back contact is completed by depositing, by D.C. sputtering, 100 nm of Mo or W. Furthermore the quality of the Sb_2Te_3 back contact has been investigated by studying the behavior of the current-voltage characteristics of the CdTe/CdS based solar cells over a period of 6 months by keeping the devices at 60 ºC in a dry ambient, under 10 suns under open-circuit conditions. Under these conditions no appreciable degradation of cells performance has been noticed apart from a slight increase in the open circuit-voltage (10 - 30 mV) while the fill factor suffered a decrease, which after repeated tests was never greater than 1%. So we can conclude that it is possible to make very stable high efficiency CdS/CdTe polycrystalline thin film solar cells by using Sb_2Te_3 as back contact on p-type CdTe films.

Conclusion

In this paper, we discussed that CdTe based solar cells the materials and processing have to be self-adjusting in a manner that the conductivity type is inverted into the absorber layer surface giving the possibility to make a homo junction. In this way the photo current becomes a majority carrier current before passing through the metallurgical interface [25]. The type-inversion is obtained by considering the inter-diffusion between the window and absorber layers that is greatly influenced by the heat treatment in chlorine ambient.

The environmental and health aspects linked to the cadmium presence in the CdS/CdTe based modules are also precisely debated in recent works. The simple argue to them is that emission of cadmiun may be hazardous but we are depositing CdTe not the cadmium alone. In fact, recycling the modules at the end of their usual life would completely resolve any environmental concern, we can conclude by asserting that during a useful life of 20-30 years, these modules do not produce any pollutant.

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Hybridization Of Photovoltaic Thermal & Biogas Power System

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Abstract:

The energy shortage and environmental pollution is becoming an important problem in these days. Hence it is very much important to use renewable power technologies to get rid of these problems. The important renewable energy sources are Bio-Energy, Wind Energy, Hydrogen Energy, Tide Energy, Terrestrial Heat Energy, Solar Energy, Thermal Energy & so on. Pakistan is rich in all these aspects particularly in Solar and Thermal Energies. In major areas of Pakistan like in South Punjab, Sind and Baluchistan the weather condition are very friendly for these types of Renewable Energies. In these areas Solar Energy can be utilized by solar panels in conjunction with thermal panels. The Photovoltaic cells are used to convert Solar Energy directly to Electrical Energy and thermal panels can be uses to convert solar energy into heat energy and this heat energy will be used to drive some turbine to get Electrical Energy. The Solar Energy can be absorbed more efficiently by any given area of Solar Panel if these two technologies can be combined in such a way that they can work together. The first part of this paper shows that how these technologies can be combined. Furthermore it is known to all that photovoltaic/thermal panels depend entirely on weather conditions. So in order to maintain constant power a biogas generator is used in conjunction with these. Moreover in last section of paper it is proposed that the controllability of system can be further improved by using MPC controller instead of PI controller.[1]

Keywords: Renewable Energy, Distributed Power system, Biogas Generator, Modeling and Simulation.

Introduction:

The worldwide demand of electrical energies is increasing day by day. But the limited resources and environmental pollution is becoming a biggest challenge for mankind.. In this frame of reference the role of every pollution less, economically efficient energy generation system is more important and considerable. Up till now the concept was that economic power generation is only possible in large power plants and in low range power plants it was not developed. But now in these days the concept of power generation in small scale by using renewable energy resources is getting more and more acceptance. The combined working of small plants depending on both renewable and non renewable resources is called distributed power system. Hence DPS can be defined as;

"It is small set of co-operatory power plants, generating electricity with renewable and non-renewable primary energy carries, working together with the help of highly advanced power electronic systems in order to fulfill the load requirement".[2].

DPSs are majorly connected to main power grid but in some cases they can work independently in order to feed some housing societies, farms and small industrial plants etc.

Obviously the major benefit of DPS is to supply far away remote areas where main grid connections is not an easy task because of the cost of connections.

The renewable energy distributed power system contains two or more renewable power generating plants, which work together in order to boost up their advantages and in order to remove disadvantages. There are many types of DPS such as:

DPS with Photovoltaic and Thermal;

DPS with Photovoltaic and Biogas;

DPS with Thermal and Biogas;

DPS with photovoltaic/Thermal and Biogas etc.[2]

All these sources are environment friendly and they don't produce pollution. The all above mentioned sources can be classified into two types, Controlled Sources and Uncontrolled Sources [2].

The controlled sources are those sources whose output power can be controlled according to demand such as Biogas Power Plants. In these Power Plant the generated power can be controlled by controlling the amount of input fuel gas.

The uncontrolled sources are those sources whose output is not controllable. These sources depend on weather conditions. For example Photovoltaic and Thermal power plant is uncontrollable because these plants depend on sun light and which is turn depend on weather conditions.

So uncontrolled plants can be used in conjunction with controlled power plants. So by using this technique the power supply can be controlled according to the load demand. In first section of this paper the Solar Panels are Photovoltaic cells are used in conjunction with Thermal Panels. Both of these are uncontrolled plants.

So after that in second section Biogas Generator is used with these in order to improve the controllability of power.

Section I:-

Photovoltaic/Thermal Energy System:

The photovoltaic cells can be used directly to convert solar energy into electrical energy. While thermal panels can be used to convert solar energy into heat energy and this energy can be in directly used to run a turbine or stuff like that to produce electrical energy. This Solar energy can be more effectively utilized by making a combined Photovoltaic/Thermal panel. In this case the overall efficiency of system will be high, over all cost will be less due to less number of controllers required and life time will be more than that of individual plants. [2]

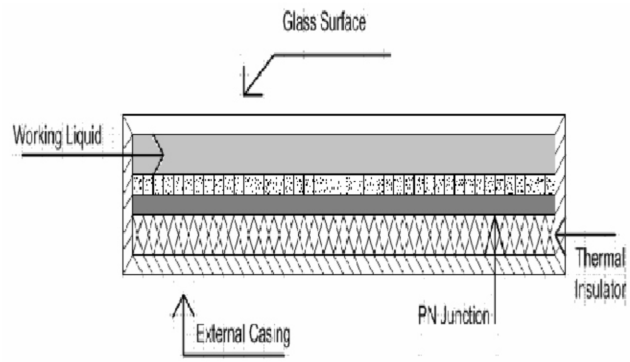

Figure 1. Construction of Combined photovoltaic/ Thermal Panel[2]

Demonstration of System:

The power generated by solar energy can be increased if Photovoltaic and Thermal technologies are combined in such a way that they work in conjunction to produce electric and heat energies. This type of combination will be very useful for Pakistan and other Asian Countries because in this region the weather is hot and sunny. Also this combined structure offers many advantages such as cost savings, efficiency and payback period[7]. The research work aimed to improve the performance of this combined system and to insure the continuity of energy with Increasing load. The simplified diagram of this structure is shown above in fig. 1.

In this structure the entire cell is divided up into two halves. The upper half is made up of transparent plastic and it carries working liquid which will be used in a heat exchanger and after that this heat will be used to run any turbine. The lower half section is the solar panel which is used to convert solar energy directly into electrical energy. The outer boundary is the protective layer of the entire system. The solar radiations which penetrate into this system are firstly utilized to heat up the working liquid and then they are used to produce free electrons in the solar panel. The upper transparent plastic layer has a special inner coating so that rays cannot be reflected back.

A complete model of Photovoltaic/Thermal panel is shown below in figure 2. The Photovoltaic panel is used directly to charge up a battery through a charge controller and the thermal cell is used to heat up a liquid which is further used to produce stream through a heat exchanger. This system is used to run a turbine. Both parts of this systems depend solely on weather conditions so an auxiliary stream generator with some heat in put can be used in order to assure the continuity of power.[1]

The Photovoltaic panel charges battery through a charge controller which prevents over charging and deep discharging of battery.

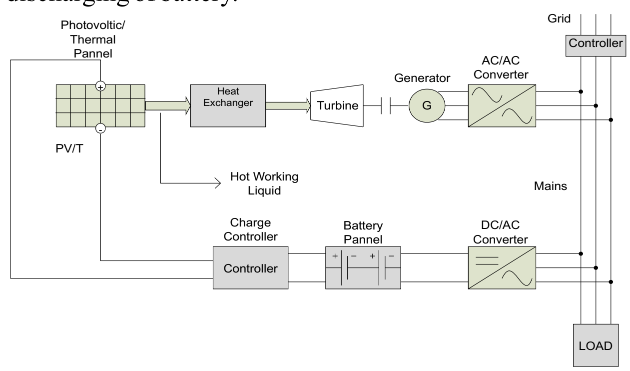

Figure 2. Complete block diagram of Photovoltaic/ Thermal DSP

Simulation Studies: The complete analysis of this system is very much difficult because of non linear nature of building blocks of this system. The energy balance for this system is very much important. This energy balance can be estimated or analyzed by calculating generating electrical power and comparing it with load demand. But load is not a linear function so it can only be estimated from past load requirement record. As simplified Matlab/Simulink model of this system with peak load of 1.5KW, rated battery voltage 48V and battery capacity of 400Ah is shown below in fig 3.

This simulation diagram consists of three major blocks, PID controller, batteries and Photovoltaic cells. The PID controller is used to control the current of DC/AC converter after accepting an error signal which is difference between reference voltage and battery actual voltage level. The Solar cell current is calculated by using solar cell V-A characteristics and an approximate radiation Vs time table. The number of series and parallel connected cells are also considered. The load current is estimated by using several past values of load current and rated load current. The solar cell current and load current corresponds to battery current from which after integrating, battery charge can be obtained. Now the charge Vs. voltage graph being stored in look up table is used to calculated battery voltage. The difference between this battery voltage and reference voltage is error signal used by controller.

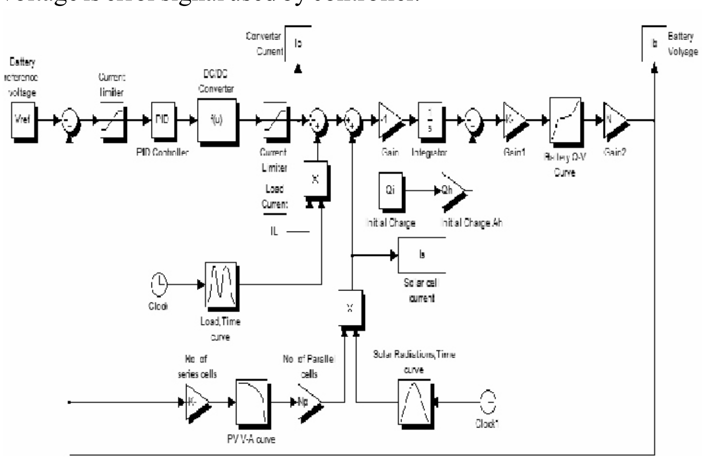

Figure 3. Matlab/Simulink model of Photovoltaic system[3]

Simulation Results:-

The simulation result of battery voltage vs. time is shown below. This simulation result is for about 70 hours, in which it clear that battery voltage increases with increasing intensity of sun light. Battery charges to it maximum value in about 38 hours. All other simulation results can be well seen by using the simulation model shown above in Matlab/Simulink. The description of entire simulation results is not possible in limited volume of this paper.

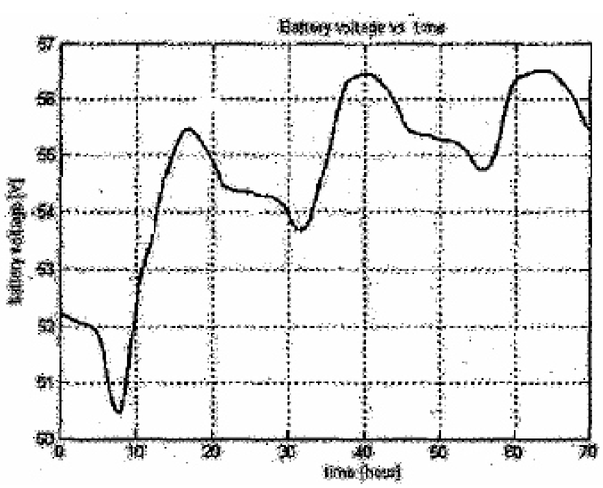

Figure 4. Battery Voltage Vs. Time

Section II:-

Combination of Photovoltaic/Thermal and Biogas Energy System:

The solar power depends on weather conditions. It is known to all that solar power changes with time and space. So DPS with Photovoltaic/Thermal power system is not suitable for continuous user needs. Biogas is generated by anaerobic degradation of organic material in the absence of air and in the presence of microorganisms [2]. The source of Biogas is waste of Industries, Agriculture and Towns etc. This Biogas is fired to drive some generator or turbines etc [2].The Biogas power generation is controlled power generation mechanism and it can be used to balance the power output from Photovoltaic/Thermal panels.

The block diagram for combined Photovoltaic/Thermal and Biogas system is shown below.

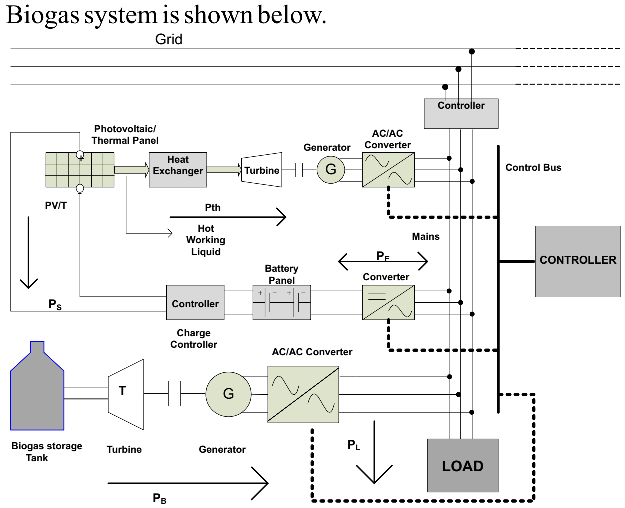

Figure 3. Complete block diagram of Photovoltaic/ Thermal and Biogas DSP

Power Flow of System:-

The current of Photovoltaic cell is DC and is supplied to AC bus bar through a DC/AC converter to change voltage level and other electrical parameters. The power generated by thermal part of cell is supplied to the AC bus bar through AC/AC converter and the power generated by Biogas generator is also fed to AC bus bar through AC/AC converter. The direction of output power is depicted in the following figure.

Now there are three relations between power generated by all these sources and load.

Case I:-

$$P_S + P_{TH} > P_L + P_E$$

This $P_G > 0$ i.e; this system will supply to grid.

Case II:-

$$P_S + P_{TH} < P_L + P_E$$

The controller will control power generated by Biogas generator and will remove deficiency i.e;

$$P_S + P_{TH} + P_B > P_L + P_E$$

And again $P_G > 0$

Case III:-

$$P_S + P_{TH} + P_B < P_L + P_E$$

Then $P_G < 0$

Hence the grid system will remove the deficiency of power.

Controller Design:-

The Photovoltaic/Thermal Biogas system is a complex system so that whole model of this system is difficult to get. In this system there are two separate controllers; One controller is the charge controller. It is a basic controller which is used to prevent battery from overcharging and deep discharge. The second controller is the major controller which compares the output power generated by Photovoltaic/Thermal panel with power requirement of load and utilized that error signal to generate command signal for Biogas power plant.

The instantaneous power generated by biogas generator is; Pi = pVin/120

Where i is amount of gas supplied in Vats.

And Pi is instantaneous power.

The output developed torque is given below;

T = 9550Pi /n

Where is efficiency.

MPC Controller:-

The second major controller which is used to control the power generated by the Bio gas generator can be replaced by an MPC controller because of its advantages over PI controller. Model predictive control is an advanced method of process control being used in process industries such as chemical plants and oil refineries etc. [4]

MPC controller uses the model of the entire system to predict the behavior of the dependent variables (outputs) of the modeled dynamic system with respect to changes in process independent variables. The predicted outputs are then compared with the actual outputs in order to generate the error signal. This error signal is used again to generate the control signals.[7]

The experimental results show that Model Predictive Control with explicit solution of the optimization problem is applicable for drive control, since the online calculation time is in the same range as for PI controllers. The performance of the Model Predictive Controller is slightly better than PI control especially in small-signal operation even with the simple machine model. Certainly, similar or even better results can be obtained using more sophisticated PI controllers with feed-forward control or disturbance compensation, but MPC offers much more facilities. Making use of these features, it should be possible to increase the control performance even more. Hence, explicit MPC might be a promising alternative to PI control for electrical drives.[5],[8].

MPC Controller:-

The second major controller which is used to control the power generated by the Bio gas generator can be replaced by an MPC controller because of its advantages over PI controller. Model predictive control is an advanced method of process control being used in process industries such as chemical plants and oil refineries etc.[4]

MPC controller uses the model of the entire system to predict the behavior of the dependent variables (outputs) of the modeled dynamic system with respect to changes in process independent variables. The predicted outputs are then compared with the actual outputs in order to generate the error signal. This error signal is used again to generate the control signals.[7]

The experimental results show that Model Predictive Control with explicit solution of the optimization problem is applicable for drive control, since the online calculation time is in the same range as for PI controllers. The performance of the Model Predictive Controller is slightly better than PI control especially in small-signal operation even with the simple machine model. Certainly, similar or even better results can be obtained using more sophisticated PI controllers with feed-forward control or disturbance [compensation, but MPC offers much more facilities. Making use of these features, it should be possible to increase the control performance even more. Hence, explicit MPC might be a promising alternative to PI control for electrical drives.

Conclusions:-

The first section of this paper suggests that Photovoltaic/Thermal panels can be used in conjunction. This system can be used in standalone mode or UPS system can also be connected to this system. In the second section it was proposed that since Photovoltaic /Thermal systems depend entirely on weather conditions hence a Biogas generator can be used along with these. By using this technique it was shown that constant output power according to the load demand is possible.

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Quotation

* The common idea that success spoils people by making them vain, egotistic, and self-complacent is erroneous; on the contrary, it makes them, for the most part, humble, tolerant, and kind. Failure makes people cruel and bitter.

W.Somerset Maugham

* Hard work without talent is a shame, but talent without hard work is a tragedy.

Robert Half

*. We must use time creatively and forever realize that the time is always ripe to do right.

Martin Luther King, Jr.

*. Time heals what reason cannot.

Seneca the Younger

*. An honourble defeat is better than a dishonourable victory

Millard Fillmore

*. The great pleasure in life is doing what people say you cannot do.

Woodrow Wilson

*. If we had no winter, the spring would not be so pleasant; if we had not sometimes taste of adversity, prosperity would not be so welcome.

Anna Bradstreet

*. The greater the difficulty, the greater the glory.

Cicero

* When people agree with me, I always feel that I must be wrong.

Oscar Wilde

* A single lie destroys a whole reputation of integrity

Baltasar Gracian

*. The greatest incitement to crime is the hope of escaping punishment.

Cicero

*. He who does not prevent a crime when he can, encourages it.

Seneca the Younger

NOTES

Ocean Power a closer look into tidal power, as well as other Ocean based power sources and their potential as a renewable energy source for Pakistan

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Engr. Sibte Ahmed Jafri is one of the senior most members of the IEEEP; Life Fellow: F 103.

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He runs a specialist Consultancy House dealing primarily with the Electrical and Mechanical Fields of Engineering.

He has been advocating for some time the concept of "buy-sell" of energy between the Utility and SPPs (Small Power Producers); unfortunately not very successfully.

Jafri and Associates work as Consultants as well as in association of foreign Consultants for Power Projects in all Technologies, both Captive and IPP; small and large; simple cycle and Combined cycle including Co-Generation.

Engr. Jafri has presented various papers at many forums. He has presented papers at the multi topic Symposium on Distribution Power Communication Skills and Rental Power.

Engr. Jafri has been advocating the use of Alternative sources of Electrical Energy, Solar, Wind and now this presentation on "Ocean Power'

Abstract

Energy is essential to all walks of life. And more specifically, electrical energy is a necessary component for the growth of a nation. Fossil Fuel (i.e. petroleum oil, coal, natural gas) is responsible for 86% of the world's energy. While we might feel secure with this fact, the truth of the matter is that fossil fuel reserves are limited and are predicted to be completely depleted within a century. The limited supply of fossil fuel, coupled with its ever increasing demand, is the reason for rising costs for today's fuel.

The oceans cover a little more than 70 percent of the Earth's surface. The affects of solar energy and celestial bodies on the ocean, make it the world's largest energy storage system. This can be seen as waves, tides, currents, ocean temperature differences, and even in as the growth of marine life. Furthermore, the ocean is source for an enormous electrical energy potential. If less than 0.1% of the renewable energy available within the oceans was converted into electricity, it would satisfy present world demand for energy more than five times over.

Developing countries, such as Pakistan, are struggling to keep up with the increased demand and subsequent costs of power and should therefore look into cheaper, renewable energy alternatives. India even has a few tidal plant projects in advanced stages of planning. This paper, looks at the different methods of harnessing ocean power, and more specifically, the feasibility and generating potential of tidal power plants in Pakistan.

Introduction

Energy is essential to all walks of life. And more specifically, electrical energy is a necessary component for the growth of a nation. It was estimated by the Energy Information Administration (US Department of Energy), that in 2006, 86% of primary energy production in the world came from burning fossil fuels (petroleum oil, coal, natural gas).1

While it may seem that this prime energy source is limitless, the truth is that we will run nearing its complete depletion. An US publication, The Oil & Gas Journal, estimates the years of production left in the ground for oil, gas, and coal is 43, 167, and 417 years, respectively (Oil & Gas Journal: World Oil). The increased demand for fossil fuel coupled with the limited supply is the reason for rising costs for today's fuel. Developing countries, such as Pakistan, are unable to cope with the increased costs of petroleum and should therefore look into cheaper, renewable energy alternatives.

Fossil Fuel also comes with inherently adverse environmental effects. The burning of fossil fuel produces excessive amounts of carbon dioxide; more than twice the amount that can be absorbed by nature. The excess carbon dioxide becomes a greenhouse gas, which leads to global warming. In the United States, more than 90% of greenhouse gas emissions come from the combustion of fossil fuels.[2]

Increased cost of fuel due to limited resources and negative environmental effects are the two main reasons why scientists are looking into Renewable Energy that is also "nature friendly".

Developing countries, such as Pakistan, are struggling to keep up with the increased demand and subsequent costs of power and should therefore look into cheaper, renewable energy alternatives. India even has a few tidal plant projects in the works. In this paper, we will look at the different methods of harnessing ocean power, and more specifically, the feasibility and generating potential of tidal power plants in Pakistan.

Ocean Based Power – An Answer

The ocean is vast. It covers 71% of the world's surface (an area of some 361 million square kilometers) and has significant impact on the earth: the ocean water is the main source for rainwater, regulates the air temperature and wind patterns, is home to millions of diverse marine life, provides a means for transportation of the world's goods, and of course, has an enormous electrical energy potential.

It has been estimated that if less than 0.1% of the renewable energy available within the oceans was converted into electricity, it would satisfy present world demand for energy more than five times over.3 The Rance tidal power station, alone, peeks at 240 megawatts of power.4 With the demand for alternative fuel rising, new renewable energy sources are being explored. Ocean based power seems to be an answer to the growing needs of the people. Some different types of Ocean Power sources are listed below.

Wave Energy

Electrical Energy can be harnessed from the energy produced by waves on the ocean's surface. Wave energy generation is still a research field and there are as many designs as companies active in this field.

One company in the US, Ocean Power Technologies Inc, has developed smart, floating buoys that drive a turbine upon its rise and fall and convert the ocean wave kinetic energy to electrical energy. Using OPT's Power Buoy® wave generation system, a 10-Megawatt station would occupy only approximately 30 acres (0.125 square kilometers) of ocean space.[5]

An Australian company, Carnegie Corporation Ltd (no relevance to the Carnegie Foundation of New York) has developed the world's first fully-submerged wave power converter unit, called CETO. The ocean's waves causes high pressure seawater to be sent via pipes to shore. This high-pressured seawater is used to generate electricity or to produce zero-emission freshwater (utilizing standard reverse osmosis desalination technology). CETO, therefore, has no need for undersea grids or high voltage transmission nor costly marine qualified plants.[6]

Although wave energy may seem like an engineer's dream, one should not forget that waves and therefore wave energy is not as predictable as the other methods of energy harnessing mentioned here.

Ocean Thermal Energy Conversion (OTEC)

The oceans cover a little more than 70 percent of the Earth's surface. This makes them the world's largest solar energy collector and energy storage system. This stored energy is in the form of temperature differences between the upper and deeper parts of the ocean water.

The US National Renewable Energy estimates that on an average day, 60 million square kilometers (23 million square miles) of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil. If less than one-tenth of one percent of this stored solar energy could be converted into electric power, it would supply more than 20 times the total amount of electricity consumed in the United States on any given day. OTEC, or ocean thermal energy conversion, is an energy technology that converts solar radiation to electric power. OTEC systems use the ocean's natural thermal gradient—the fact that the ocean's layers of water have different temperatures—to drive a power-producing cycle. As long as the temperature between the warm surface water and the cold deep water differs by about 20°C (36°F).[7]

In May 1993, an open-cycle OTEC plant at Keahole Point, Hawaii, produced 50,000 watts of electricity during a net power-producing experiment. This broke the record of 40,000 watts set by a Japanese system in 1982. Today, scientists are developing new, cost-effective, state-of-the-art turbines for open-cycle OTEC systems.[8]

Osmotic Power / Salinity Gradients

When a river runs into the ocean and the freshwater mixes with the saltwater, huge amounts of energy are unleashed. By placing a semi-permeable membrane (i.e. a membrane that retains the salt ions but allows water through) between reservoirs containing freshwater and seawater, respectively, a net flow of water towards the saltwater side will be observed.

Osmotic Power, or less commonly known as Salinity Gradient Power, is the energy retrieved from the flow of water from the freshwater side to the saltwater side. If the saltwater compartment has a fixed volume the pressure will increase towards a theoretical maximum of 26 bars. This pressure is equivalent to a column of water 270 meters high. It is estimated that each year 1600 TWh (terawatt-hours) could be generated worldwide.

The osmotic power plant is very area efficient. A 25 MW plant would only require some 40,000 m2 of land even if it is located above the ground. Wind farms or biomass harvest sites would require a relatively larger area of land to produce the same amount of energy.

Two practical methods for this are Reverse electro dialysis (RED), and Pressure retarded osmosis (PRO). The PRO power plant is similar to a reverse osmosis desalination plant running backwards. A Norwegian company, Statkraft, has announced that it will build a PRO plant prototype in Hurum in Buskerud. Construction of the prototype started in 2008, and was planned to produce 2 to 4 kilowatts.[9]

One of the major obstacles that deter groups to invest in such power plants is the high cost of the membranes. Not to mention, the fact that marine animals can be "sucked" in to such membranes.

Marine (Algae) Bio-fuel

Marine algae offer a vast renewable energy source for countries around the world that have a suitable coastline available. Utilising marine as opposed to terrestrial biomass for energy production circumvents the problem of switching agricultural land from food to fuel production. In addition, the production of marine biomass will not be limited by freshwater supplies, another of the contentious issues of increasing terrestrial bio-fuel production.

Algae have the capability to grow rapidly in sunlight and can have a high percentage of lipids or oils depending on the species. It can double its mass several times a day and produce at least 15 times more oil per acre than alternatives such as rapeseed, palms, soybeans, corn or jatropha. Algae with a good lipid factor (vegoil in relation to algae cells) can be made into vegetable oil, bio-diesel, bio-ethanol, bio-gasoline, bio-methanol, biobutane and other bio-fuels [10]

Previous studies have shown that marine algae are as good a feedstock for anaerobic digestion (AD) processes as terrestrial sources. Marine algae contain no lignin and little cellulose; demonstrate high conversion efficiencies, rapid conversion rates and good process stability. And to top if off, the by-product residue is suitable for use as nutrient supplements for agriculture.[11]

The Nature of Tides & Tidal Energy

Tidal Phenomena

The word tide refers to the rise and fall of sea level relative to the land. Such vertical movements (as compared to the horizontal movement seen in "tidal currents", which too, can be utilized to produce mechanical energy) differ considerably according to seasons, astral alignment, and other factors, including geomorphology. The movement is produced by the gravitational attraction, the "pull" of several celestial bodies, but overwhelmingly by that of moon and sun. The "pull" of the moon is the strongest because, although of smaller mass than the sun, it is far closer to earth.

Tides are classified according to recurrent phase within a tidal day (which is 24 hours and 50 minutes long). Those that display one high tide and one low tide are called diurnal. Two high and two low tides are called semidiurnal (Figure 1). And there are mixed tides, which display characteristics of both diurnal and semidiurnal tides. The majority of the coasts, including that of Pakistan's, are of the semidiurnal type, and therefore, two high tides and two low tides are witnessed daily.

Figure 1-Semidurnal Tidal Day

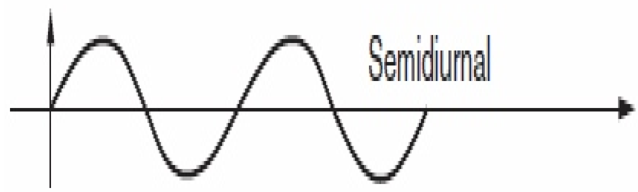
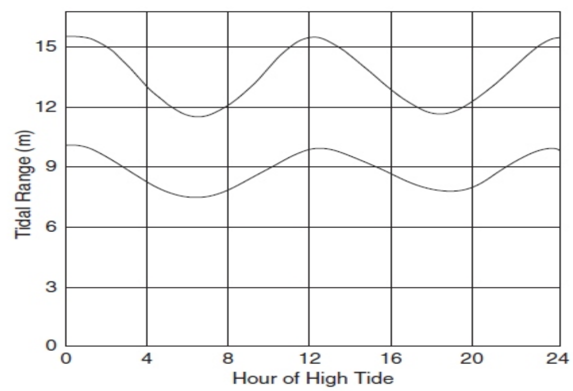


Figure 2 High & Low Tides of a Semidurnal Tidal Day



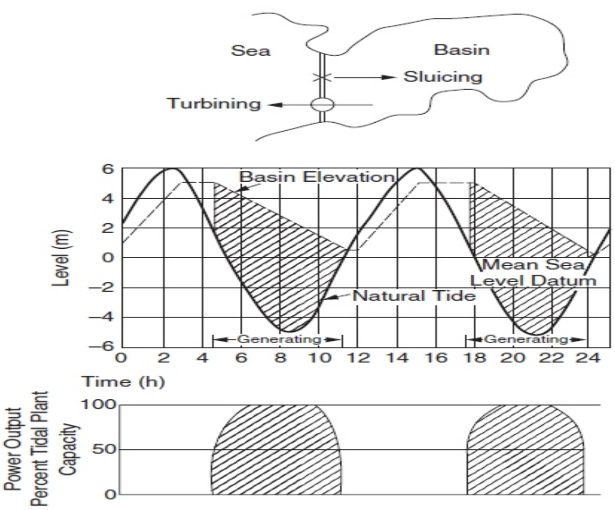
Tides occur in an orderly fashion and are predictable. Yearly, the differences between tides are minor and repeat themselves every 19 years. There is also a relationship between the tidal range and hours of high and low tide so that, at a particular location and at a specific time during the day, the tidal range to be expected will always be within known values.

Simply put, mechanical and electrical energy is harnessed from the rising and falling of tides. Theoretically the rise and fall of the tides dissipates 3,000 million kW of which one billion in shallow seas.

Tidal Power Plants

Tidal Power Plants are the forerunner to yesteryear's tide mills which have been used throughout the world for hundreds of years. In the tide mill system, tidal water is trapped in a reservoir during high tides (flood tide). When the tide drops (ebb tide), the water behind the reservoir flows through a channel where a power turbine is placed. The water flowing through the channel spins the turbine and, therefore, generates electricity. Unlike wind and wave power, tidal streams offer entirely predictable output. However, there exist such tidal power plants1 that generate power (spin the turbine) not just during the ebb tide, but also during the flood tide, by utilizing reversible turbines. These reversible turbines can be seen at the Rance power plant and provides more power potentially generated. Ideas are even being suggested to generate extra power from buoyancy and weight in the reservoirs, at ebb times.

Figure 3 Single-basin, single-effect scheme, and its output



The energy provided by tides, though intermittent, is regular and inexhaustible because it is constantly renewed. A mill functions from three hours before to three hours after low tides. The most common location of tide mills is of course on coasts where tides have large amplitudes. Most mills are found in estuaries, on tidal channels, or within bays. Others, tough fewer, are on islands or peninsulas on rocky coasts or on the beach Itself.

Table 1 Prospective sites for tidal energy [15]

Prospective sites for tidal energy projects						
Country	Country	Mean tidal range (m)	Basin area (km^2)	Installed capacity (MW)	Approximate annual output (TWh/year)	Annual plant load factor (%)
Argentina	San Jose	5.8	778	5040	9.4	21
	Santa Cruz	7.5	222	2420	6.1	29
Australia	Secure Bay	7.0	140	1480	2.9	22
	Walcott Inlet	7.0	260	2800	5.4	22
Canada	Cobequid	12.4	240	5338	14.0	30
	Cumberland	10.9	90	1400	3.4	28
	Shepody	10.0	115	1800	4.8	30
India	Gulf of Kutch	5.0	170	900	1.6	22
	Gulf of Khambat	7.0	1970	7000	15.0	24
UK	Severn	7.0	520	8640	17.0	23
	Mersy	6.5	61	700	1.4	23
USA	Pasamaquoddy	5.5				0
	Knik Arm	7.5		2900	7.4	29
	Turnagain Arm	7.5		6500	16.6	29
Russian Fed.	Mezen	6.7	2640	15000	45	34
	Tugur	6.8	1080	7800	16.2	24
	Penzhinsk	11.4	20530	87400	190	25

The three fully functioning, and large-scale projects are cited when speaking of TPP, those are: the Rance TPP (France), Russian North, and a Canadian plant in Nova Scotia. It should be mentioned that the development of TPP was boosted by the developments of these three power plants: the bulb turbine by France & Russia and the Straflo turbine by Canada.

The Rance TPP opened in November 1966 and is the world's first major electrical generating station powered by tidal energy. It uses a 330 meter long dam, consisting of 24 Bulb type turbine generators, 5.35 meters in diameter, 470 tons in weight, and rated at 10MW each which generate electricity whether the tide is going in or out. These Bulb turbines permit reversible operation and pumping. Although the peak power capacity is 240MW, the average power generated is 68MW for an annual output of around 600 million kWh units of electricity.[4]

In November 1996, the Rance celebrated 30 years of active service during which time 16 billion kWh of electricity were generated without major incident or mechanical breakdown. The plant's costs of 620 million Francs (-roughly 94.5 Million Euros, for a cost of 0.4 million Euros per megawatt) have now been recovered. The electricity production costs are lower than for other fuel types (0.018 Euro per kW, or $0.02 per kW. The cost to produce electricity in Pakistan ranges from 4.5¢ to 12¢ (USD). Today, the Rance TPP also serves as a tourist attraction and attracts 200,000 visitors per year.[12]

Figure 4 - Aerial view of La Rance (Courtesy of Phototheque EDF: M. Brigaud)

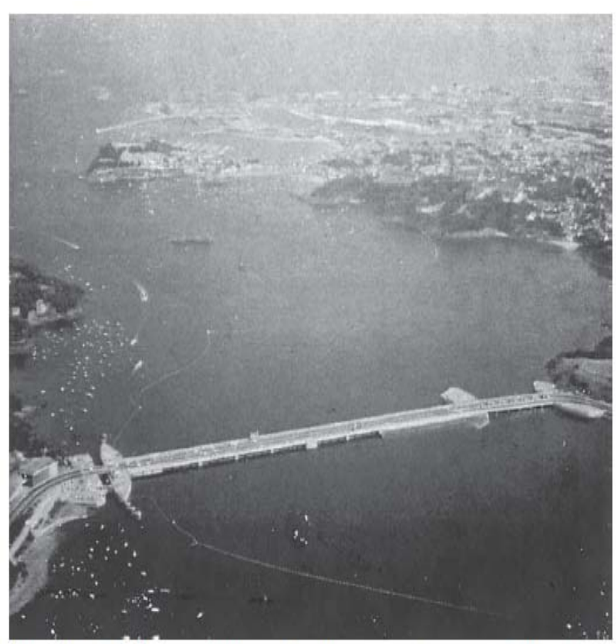


Figure 5-General layout of La Rance tidal-electric station

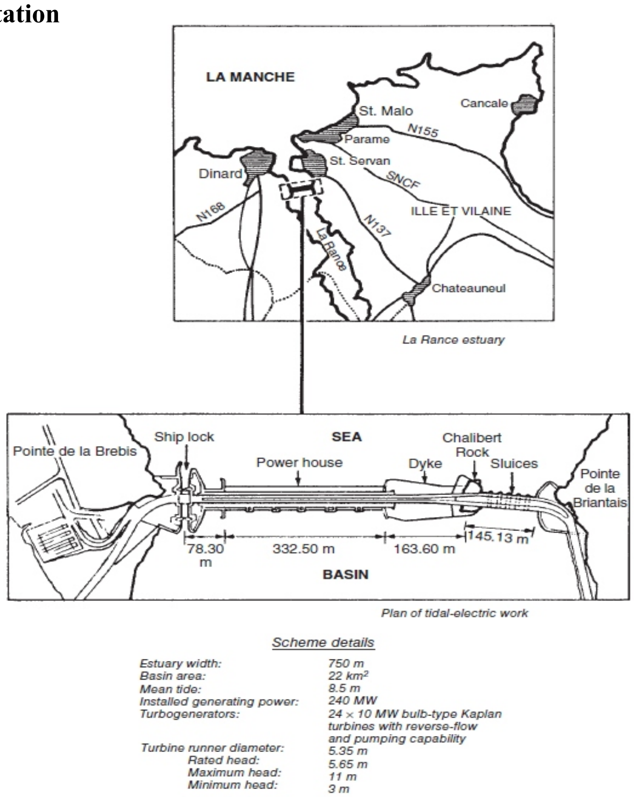


Figure 6-Sectional elevations of component structures. (From Cotillon, 1979)

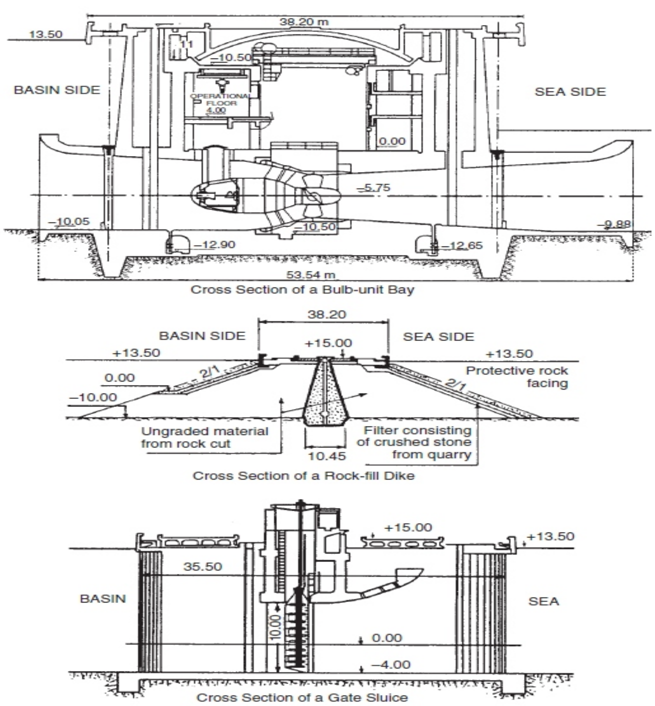


Figure 7-Variations of tide range at La Rance

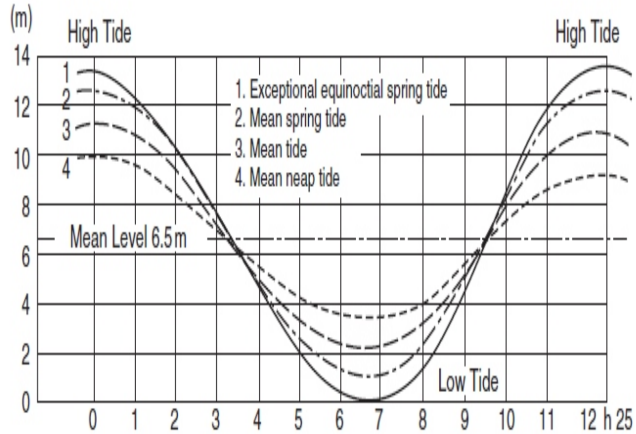
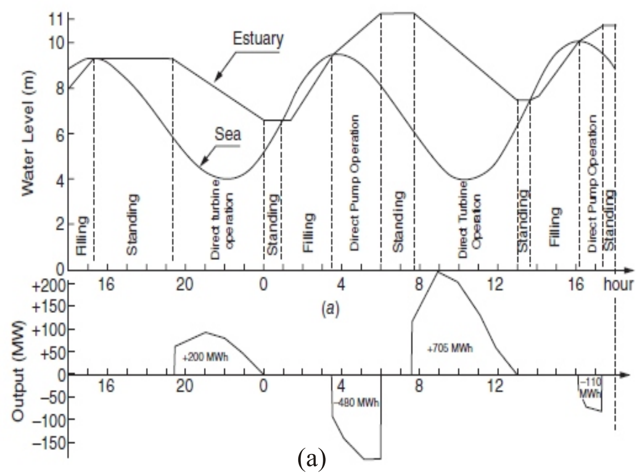


Figure 8 - Operational mode and output for large and small tidal ranges. (a) Single - effect operation and (b) double-effect operation. (From Electricite de France, 1992).



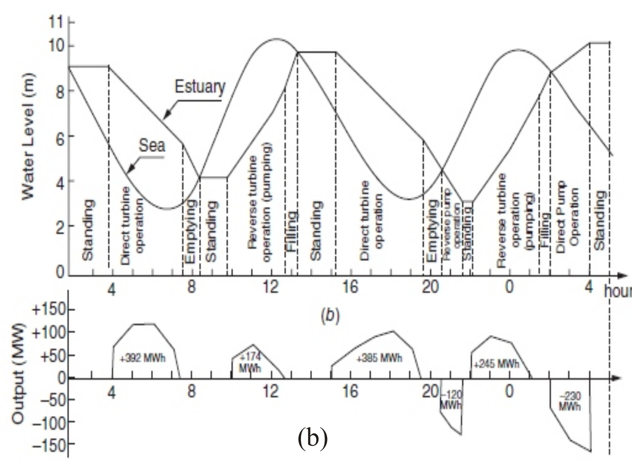
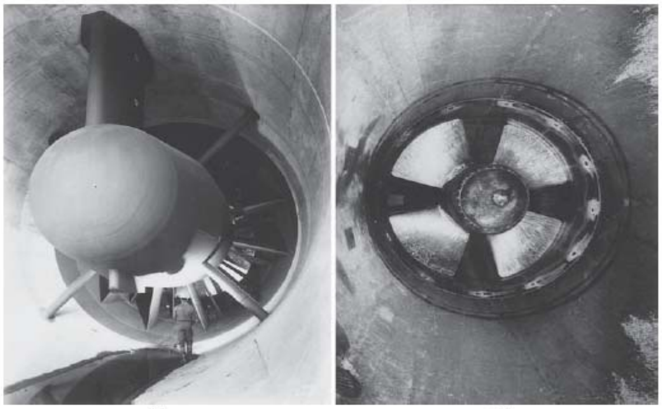


Figure 9-Views of La Rance bulb turbogenerator: (a) View from basin side. (Courtesy of H. Baranger et Cie.) (b) view of runner from sea side. (Courtesy Doucet-Dinard.)



(a) (b)

with large tidal ranges. The development of very small head turbines permits the implantation of TPPs in many more locations. With Pakistan's coast yielding an average of 3-4m tidal range, this seems like a feasible solution (Tide Tables for 2008, Pakistan Navy Hydrographic Department).

Studies found that the cost of a tidal plant kilowatt is today hardly higher—if indeed it is—than that produced by a conventional central or even a nuclear plant. Capital costs remain high for a tidal power plant but the longevity of the tidal plant is given at 75 years compared to 25 for a fossil fuel thermal central and between 30 and perhaps 40 years for a nuclear one.

More modestly even, reintroduction of tide mills in appropriate and selected sites may prove to be a profitable very low cost investment. Studies also show, Lower production costs can be obtained with larger basins and larger tidal ranges. But large basins require long dams thus a bigger capital investment, though by doubling the dam's length basin size is quadrupled!

No major new technologies are needed for the current construction of tidal power plants, however, it may pay off to foster development and research the interface of a central's output with national grids, calculate a sound estimate of its economic interest, design and site proper implanting, and of course environmental effect and sustainability. [13]

As mentioned earlier, tidal streams & waves are predictable and are available by many marine information agencies throughout the year. Such information, although limited, can be found on the Pakistan Meteorological Department website14 and via the annual "Tide Tables" publication. Because of the abundance of water available to a tidal plant, emphasis of design is more on maximum output than on maximum efficiency, the latter being of more importance in river hydro developments. Thus, the output of a tidal plant is determined by the following interrelated factors: (1) usable head that varies continuously with the tidal regime and is modified by the fluctuation of basin levels resulting from operation of the plant; (2) the area of the tidal basin; (3) the capacity of the sluices used to fill or empty the basin; (4) the capacity of the generating units; and (5) the method of operation selected.

For a tidal site, the available energy (and peak capability) depends largely on the installed capacity within very wide practical limits. Basin size and tidal range do, of course, define the theoretical or gross energy potential (GEP) of a site.

GEP = 2793AR^2 kWh per tide, where **A** is the area of the basin in square kilometers, and **R** is the tidal range in meters. Yearly GEP for a semidiurnal site (705 tides per year^2) is calculated as: **GEP = 1.97 X 10^6 AR^2 kWh annually.** Average power can be calculated as: **Average power over tidal cycle = 225AR^2 kW.**[12]

It should also be noted that tidal engineering practice, based on the results of preliminary studies of tidal sites at various locations on the globe, usually allows an optimal annual energy production (AEP) for a single-basin site generating on the ebb flow of about one-third of the GEP. It is emphasized that the value obtained is an order-of-magnitude estimate only. Since tidal ranges are fixed, one can increase the basin size to increase the GEP and AEP of a site.

The capital cost of TPPs (see Table 2 below) is about 3000 Euros/kWh ($3959/kWh). The operation and maintenance (O&M) cost is relatively similar to hydro power plants.

Table 2 - Comparison of Capital Costs (see endnote 15)

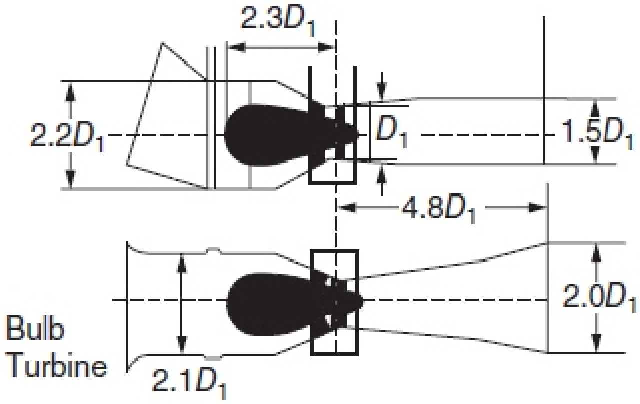
Comparison of Capital costs							
RES-E Sub category	Plant Specification	Investment Costs	O&M Costs	Efficiency (electricity)	Efficiency (heat)	Lifetime (average)	Typical plant size
		[E\kw]	[E\kw/year]	[1]	[1]	[Years]	[M/W]
Wind onshore	Wind power plant	945-1050	36-40	-	-	20	2
Wind offshore	Wind power plant - near shore	1750	65	-	-	25	5
	Wind power plant -off shore 5.30 km	1950	70	-	-	25	5
	Wind power plant -off shore 30.50km	2150	75	-	-	25	5
	Wind power plant-offshore 50 km	2400	80	-	-	25	5
Geothermal electricity	Geothermal power plant	2000-3500	100-170	0.11-0.14	-	30	5-50
Hydro large-scale	Large-Scale unit	850-3850	35	-	-	50	250
	Medium scale unit	1125-4875	35	-	-	50	75
	Small scale unit	1450-5950	35	-	-	50	20
	upgrading	800-3800	35	-	-	50	-
Geothermal electricity Hydro small. scale	Large scale unit	800-1800	40	-	-	50	9.5
	Medium Scale unit	1275-5025	40	-	-	50	2
	Small Scale unit	1550-6050	40	-	-	50	0.25
	Upgrading	900-3700	40	-	-	501	-
Photovoltaics	PV plant	5400-6300	40-50	-	-	25	0005-0.05
Solar thermal electricity	Solar thermal power plant	2900-4500	165.230	0.33-0.38	-	30	2-50
Tidal energy	Tidal (stream) power plant -shoreline	3000	50	-	-	20	0.5
	Tidal (stream) power plant-near shore	3200	55	-	-	20	1
	Tidal (stream) power plant-offshore	3400	60	-	-	20	2

Turbines

The choice of concept for the hydraulic machinery is of the greatest importance for the economy of a tidal power plant, which must exploit energy under low to very low heads. The only turbine types adaptable to such plants are the axial-flow, high specific-speed turbines, of which there are four basic types: kaplan, tube, bulb, and straight flow (Straflo). Below we will discuss two of the most popular turbines used today: bulb and straight flow.

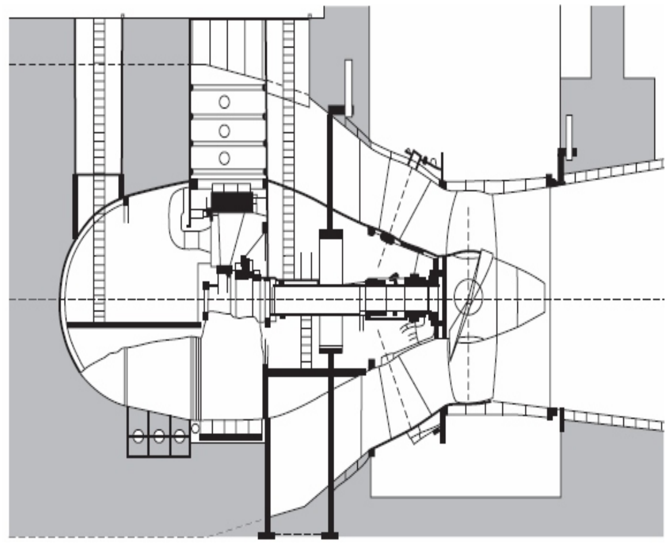
1) Bulb Turbines

Figure 10 - Overall dimension of a Bulb Turbine



The bulb turbine operates in a straight water passage with the generator enclosed in a bulb. The bulb turbo generating unit is characterized by improved hydraulic efficiency, greater discharge capability, and greater power output for the same runner size than other designs. Moreover, it reaches higher specific speeds than the Kaplan turbine and so can be used to exploit even lower heads.

Figure 11 - Cross section of a bulb turbine with direct-driven generator for Racine hydropower plant (United States). (From Miller, 1978)



The bulb turbine has contributed significantly to the development of low-head hydro projects, enabling the exploitation of heads between about 1.5 to 20 m. Its characteristics are well developed and almost all recent installations for large, low-head, river schemes have used bulb turbines. Bulb turbine also has had the advantage of experience and expertise in its design and use, as it can be seen in action at the Rance TPP in France, and it is generally chosen as the machine on which to base tidal output optimization and civil works. Table 3 lists some of the major low-head installations since 1967.

Table 3 - Some Major Low-Head Installation Since 1967

Country	Location	Turbine Diameter (m)	Speed (rpm)	Generator Size (MW)[a]	Rated Head (m)	No. of Units	Date of Commissioning	Type of Turbine	Method of Cooling Generator
Austria	Altenworth	6.0	103.4	38.9	14	9	1976	Bulb, double regulated	Pressurized air
Canada	Jenpeg, Manitoba	7.5	62.1	31.1 @ 60 Hz	10.7	6	1977	Bulb, double regulated	Direct water
	Annapolis Royal	7.6	50	20 @ 60 Hz	5.5	1	1984	Straflo, single regulated	Air
France	Peage-de-Roussilon	6.25	93.8	40	12	4	1977	Bulb, double regulated	Pressurized air
	Caderousse	6.25	93.75	31.5	9.5	2	1975	Bulb, double regulated	Pressurized air
	Caderousse	6.9	93.75	31.5	9.5	4	1975	Bulb, double regulated	Pressurized air
	Sauveterre	6.9	93.8	33	9	2	1973	Bulb, double regulated	Pressurized air
	Avignon	6.25	93.8	30	10	4	1973	Bulb, double regulated	Pressurized air
	La Rance	5.35	93.75	10	5.75	24	1966/7	Bulb, pump-turbine	Pressurized air
Germany	Iffezheim	5.8	100	28.3	11.7	4	1977	Bulb, double regulated	Pressurized air
United States	Ozark	8	60	25 @ 60 Hz	10.6	5	1970	Tubular, double regulated	Air
	Harry S. Truman	6.45	94.7	31.5 @ 60 Hz	24	6	1976	Tubular, pump turbine	Air
	Rock Island	7.4	85.7	54 @ 60 Hz	12.1	8	1978	Bulb, double regulated	Pressurized air
	Racine	7.7	62.1	24.6 @ 60 Hz	6.2	2	1981	Bulb, double regulated	Pressurized air
	Vidalia	8.2	52.2	24 @ 60 Hz	4.9	8	1989	Bulb, single regulated	Pressurized air

[a] At 50 Hz unless shown otherwise.

2) **Straight-Flow (Straflow) Turbine**

Figure 12-Overall dimension of a Straight Flow Turbine

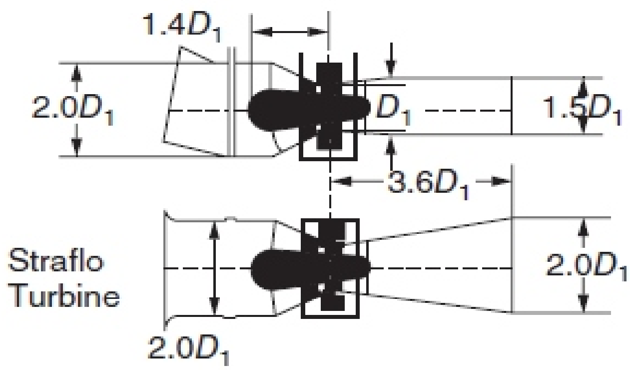
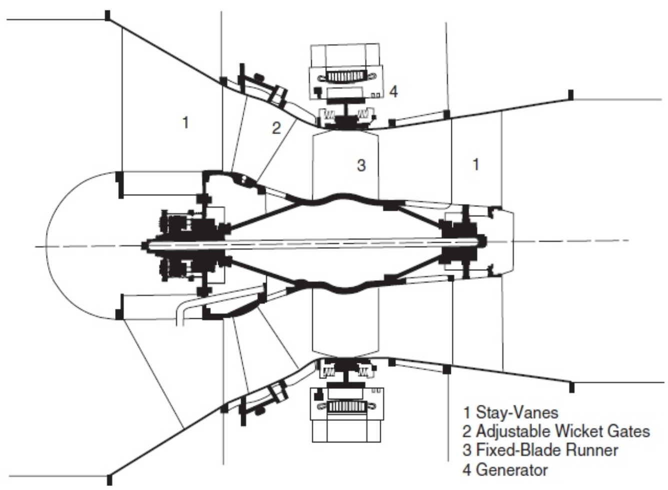


Figure 13 - Typical cross section of a Straflow turbine (From Miller, 1978)



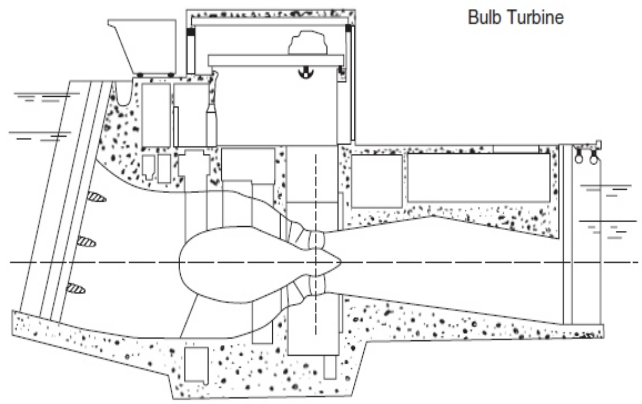
The concept of mounting the generator rotor on a rim fixed peripherally to the runner blades (also known as a rim-generator turbine, was patented in 1919 by Harza.

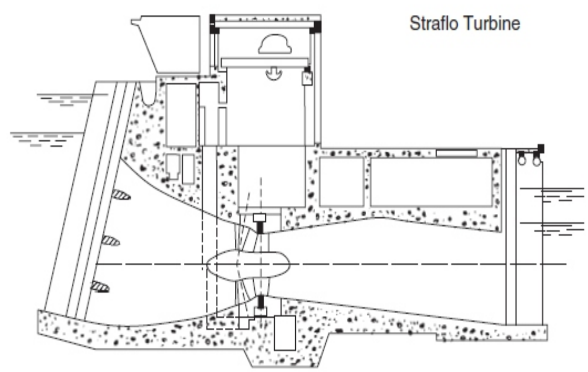
These turbines are used at the Annapolis Tidal Generating Station in Nova Scotia, Canada, commissioned in 1984. This station contains one 7.6-m-diameter Straflo turbine with a maximum rated output of 19,600 kW under a rated head of 5.5 m.

The Straflo turbine does not have the obstruction of a large bulb containing the generator in the waterway so that hydraulic losses are lower. The absence of the "bulb" results in shorter, less expensive, and more hydraulically efficient water passages. Moreover, since the Straflo generator is outside the turbine water passages, that is, it is not in a steel shell in the water, it is more easily accessible for maintenance.

During its ensuing period of operation for Annapolis Demonstration Project (from 1984 through 1996), the relatively few problems encountered have been associated with auxiliary equipment rather than the turbine design as such. The turbine runs very smoothly and quietly and has operated with a high level of availability since it entered commercial service. It provides rated output at rated head and has required relatively little maintenance.

Figure 14-Comparison of Straflow and bulb turbine power houses for the same output





Tidal Power Seen in India

This paper has already described a plethora of the various power generating options. Each of them can potentially be harnessed in Pakistan given the opportunity. As best as it can be determined at this point in time, there are no ocean-power projects being planned or studied in Pakistan. However, marine data is collected and available by different government agencies. This data can be used to predict tidal flow and power generation potentials. Before going further, a brief look at the tidal power scene in India is presented below.

India has so far identified three possible locations for tidal power plant development: the Gulf of Kachchh, Gulf of Khambhat on the west coast in Gujarat Province, and in Sunderbans along the east coast in West Bengal.

Table 4 - Prospective sites for tidal energy projects in India (Taken from Table 1)

Prospective sites for tidal energy projects						
Country	Country	Mean tidal range (m)	Basin area (km^2)	Installed capacity (MW)	Approx. Annual output (Twh/year)	Annual plant load fact (%)
India	Gulf of Kutch	5.0	170	900	1.6	22
	Gulf of Khambat	7.0	7.0	7000	15.0	24

The country's first small-scale, tidal power generation project is coming up at Durgaduani Creek of the Sundarbans. The maximum tidal range in Sunderbans is approximately 5 m with an average tidal range of 2.97m. The 3.75MW capacity Durgaduani Creek tidal energy project is a technology demonstration project and will span over an area of 4.5 sq km. It is expected to cost 9.5 million U.S. dollars. [15]

A feasibility study to exploit the energy potential for a larger tidal plant at the Gulf of Kachchh was launched in 1982 and completed in 1987. The development proposed for this gulf would be a single basin with the main tidal barrier, about 3.25 km long, constructed across Hansthal Creek. The installation would consist of 36 adjustable-blade bulb turbines, 8.5 m in diameter and with a capacity of 25 MW under a rated head of 5 m; the maximum head would be about 7.5 m. The total installation of 900 MW would yield an annual output of about 1690 GWh.16 As can be seen from Table 4, these figures account for an annual plant load factor which is usually between 20-30%. In Kachchh TTP's case, the load factor is 20-22%. The Kachchh tidal project is estimated to cost about 289 million U.S. dollars, generating electricity at about $0.17 per kWh. The technoeconomic feasibility report is now being examined.

Table 5-Tidal Characteristics in Gulf of Khambhat and Kachchh

Location	Spring Range (m)	Neap range (m)	Average range (m)
Bhavnagar (Gulf of Khambhat)	10.29	3.6	7.0
Navlakhi (Gulf of Kachchh)	7.17	3.74	5.45
Kandla (Gulf of Kachchh)	6.32	3.68	5.00

The Pakistan Model

By looking at the current developments in India, one can compare variables and deduce similarities, which can aid the study of a potential tidal power plant in Pakistan.

The Pakistan Meteorological Department, with the collaboration of the Pakistan Navy Hydrographic Department, has installed sensors at seven different stations across the coast of Pakistan. The locations of these stations consist of major and minor ports, harbors, and entrances. The sensors collect hourly, tidal flow data around the clock and this data is then published annually under the title of "Tide Tables". Tide Tables can be used to predict ebb and flood times, potentials energy output, and accordingly, financial viability. A list of the stations, along with their annual tidal statistics for 2009, is listed in the table below.

Table 6 Pakistan's Annual Tidal Statistics for 2009

Location	Average Flood Time	Average Ebb Time	Avg Tidal Range3 (meters)	Larg. Tid. Rnage (meters)
Karachi	6hr 13min	6hr 11min	1.60	3.63
Port Muhammad Bin Qasim (Entrance)	6hr 19min	6hr 6min	1.70	3.93
Port M. Bin Qasim (Pipri)	6hr 42min	6hr 42min	1.85	4.50
Ormara	6hr 6min	6hr 18min	1.35	2.98
Pasni	6hr 7min	6hr 18min	1.55	3.08
Gwadar	6hr 7min	6hr 17min	1.35	3.04
Hajambro Creek (Entr.)	6hr 22min	6hr 3min	1.74	3.44

As can be seen, the Port Muhammad Bin Qasim (Pipri) has the largest, average tidal range and longer flood/ebb times than any other location. And because of this reason, the calculations that follow have been focused for this location, henceforth referred to as simply, Port Qasim (Pipri).

Port Qasim (Pipri)

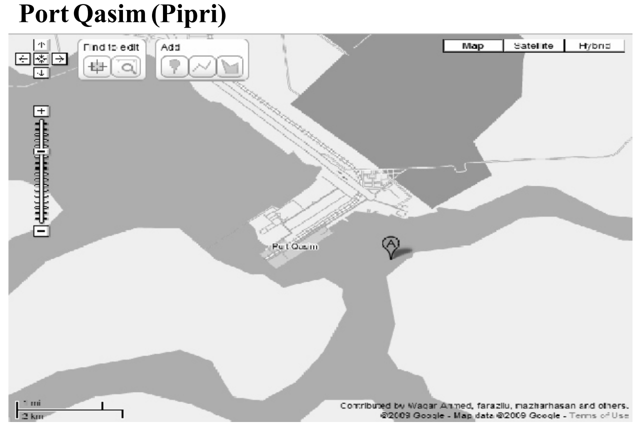
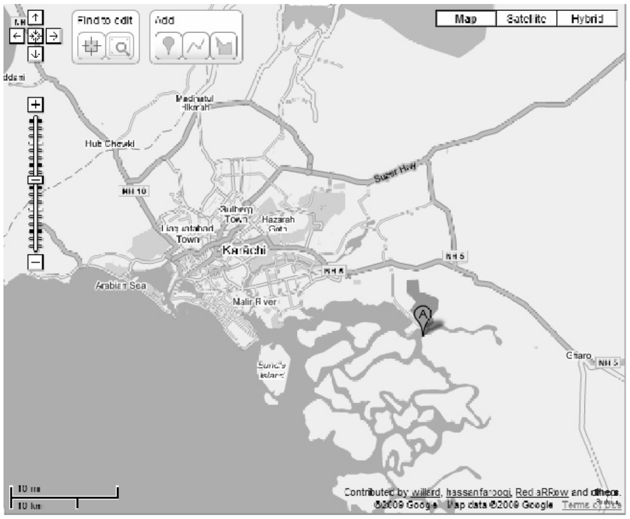


Figure 16-Port Qasim (Pipri) relative to Karachi



Port Qasim (Pipri) is located at 24.766667 N, 67.35 E and is about 40km from Karachi's center. Though the average tidal range for Port Qasim (Pipri) is a bit less compared to India's Gulf of Kachchh tidal range, there have been significant developments in low-head turbines which could yield sufficient output. It is recommended that Bulb turbines be used because they are newer and more cost efficient than straight flow turbines.

The tides across the coast are of semidiurnal nature, which provide two ebb times in a tidal day, and subsequently, have two power-generating time periods in the day. This would equate to two times the power generating potential as compared to diurnal tides.

If in theory a power plant was built in Port Qasim (Pipri) with a basin area of 4.5 sq km, the Gross Energy Potential (GEP) with tidal ranges displayed in Table 6 (1.85m), would come out to be: 43,015 kWh per tide, or 30,340 mWh annually (705 tides in a year), with the average power over tidal cycle being 3.465 mW.4 With a load factor of 30%, the GEP will be 9.1GWh per year.

The 900mW Gulf of Kachchh TPP is estimated to cost $228.3 million; with the investment being approximately $320.4 per kW. Since the Port Qasim TPP is a much smaller project than the Kachch TPP, its cost per kWh will higher. The Port Qasim (Pipri) TPP may cost approximately $3.5 million, with the cost per kWh being $0.38.

It important to mention that the tidal range figures shown in Table 6 are yearly averages and there will be times when the tidal ranges are larger.

Conclusion

Pakistan is gifted with a really long sea shore. The entire shore is a potential location for "Ocean Power" using one or more of the technologies listed in this paper. The electrical power so produced shall be used for uplifting the standards of the local population which is one of the most deprived in the Nation.

The estimated cost per unit does appear a little higher but if compared with the cost of Transmission and Distribution Network that would be needed to bring power produced hundreds of miles away, the economics may become quite comparable. Besides a case can be made for the Federal Government subsidizing the cost for Power Generation from the Ocean, for the sake of service to the backward area. Possibility of pickup of mini industrial activity particularly covering the fishing and preservation of local produce e.g. dates and many other intangible benefits can be foresee.

The electricity produced shall be wholly free of carbon emission and therefore international aid and support is possible if suitable case is made.

It is proposed that the IEEEP, in association of the Hamdard Engineering University (which is very active in the Energy Sector) conducts a mini study to setup at least an experimental station in the Pipri region which being close to Karachi is quite accessible and may serve a good demonstration piece for the international aid-giving agencies and/or Pakistan Science Foundation.

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Quotation

*. The space in needle’s eye is sufficient for two friends, but the whole world is scarcely big enough to hold two enemies.

Ibn Gabirol

*. The opposition is indispensable. A good statesman, like any other sensible human being, always learns more from his opposition than from his fervent supporters.

Walter Lippmann

*. As the sutra says, a parasite in the lion’s bowl will devour the lion. A man of great fortune cannot be ruined by his enemies, but only by those close to him.

Nichiren Daishonin

*. Pay attention to your enemies, for they are the first to discover your mistakes.

Antisthenes

*. I would prefer even to fail with honour than to win by cheating.

Sophocles

*. It is not a disgrace to fail. Failing is one of the greatest arts in the world.

Charles F. Ketting

* Our greatest glory is not in ever falling but in rising every time we fall.

Confucius

* If you wish to be loved, show more of your faults than your virtues.

Edward Bulwer - Lytton

* Our short comings are the eyes with which we see the ideal.

Friedrish Wilhelm Nietzche

* Hungry men have no respect for law, authority, or human life.

Marcus Gravey

* Defeat should never be a source of discouragement but rather a fresh stimulus.

Robert south

*. The greatest mistake you can make in life is to be continually fearing you will make one.

Elbert Hubbard

Power System Earthing and Safety

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Abstract: -

The power System/distribution system in interrupted due to poor earthing system which is very dangerous to human being and system too the large number of factors that must be considered is partly responsible but primarily it is because most of these factors cannot individually be set up in terms of conflicting influences. There are various methods for condition monitoring. This is article describes different techniques of application of earthing. The ground electrode with low resistance does not guarantee that the difference in potential between the possible points of contact will also be tolerable.

1. Basic concept.

Earthing is achieved by electrically connecting the respective parts in the installation to some system of electrical conductor or electrode placed in intimate contact which sole some distance below the ground level. This contacting assembly is called earthing. [2]

Reduction of shocks of hazards to human being by controlling the voltage level which are come in contact with live network. [1] [3]

The purpose of this article is review earthing practices with special references to safety, to design the earthing system. The potential difference is in safe limit under abnormal conditions. Method for obtaining data for designing of power system earthing. There are concerned with both in door and out door substations. Power system earthing is designed degree of protection and step wave front surges entering the station and passing to earth through its earthing system. [2] [5].

2. Design consideration

Design is totally depends on regular research for the performance of design. Air termination net work concept introduces of all types of high buildings and equipments all these are in vertical position no part of roof in the air termination network. The network mesh of 10 mtr x 20 mtr various type of down conductor are used. They are conducted for air and earth termination and good is offered by this method. Various techniques are used for improving the resistance. They are [4][6].

1. Deep driven earth electrodes.
2. Parallel earth rod electrode.
3. Radial strip electrode.
4. Solid plates or mats.
5. Re- enforcing bars in foundation as natural earth.
6. under ground pipe work system

and etc.

2.1 Basic design requirements.

1. No earth plants should be less than 2ft x2 in area and 1/8 inches copper.
2. If lower resistance is required for an installation connects two or three more plates in parallel. All of 2ft x2ft keeping every plate at less 10ft away from other.
3. Every plate is buried at less 10ft away from the electrode of any other type of earthing e.g. single circuit ratio and lighting rods
4. if electrical apparatus is present than at leas two plates are installed at maximum distance but never less than 10 ft.
5. The plate, which is buried, the buried conductor or plate is at least 1ft below permanent level [2] [5].

3. Methodology And Advance Techniques

The basic requirement for earthing are:-

1. Preliminary design for earthing system.
2. Behaviour and atmospherioc characteristics of soil
3. Maximum earthing current and ground current determination by different methods.
4. Power system earthing resistance calculation
5. Behaviour of step voltage Periphery base on the actual measurement.
6. Touch voltage and step voltage measurement with reference to the actual measurement.
7. Construction of earthing for power system.
8. Field measurement of resistance of earthing system.

Electrical resistivity tests are desirable. These tests are made a number of places with in the site. The resistivity is different at different location and depth, so it is used a range of probe spacing which is sufficient to accurate estimate for earthing of power system. The electrode resistance is as;

$$\rho = \frac{2\pi AR}{1 + \frac{2A}{\sqrt{A^2 + 4B^2}} - \frac{2A}{\sqrt{4A^2 + 4B^2}}}$$

Where

$$\rho = 2\pi AR.$$

R= The resistance in ohms.

A= Adjacent electrodes distance in meters.

B= Electrode depth in meters.

Therefore

The earthing system will be installed after the yard has been graded and deep excavation have been back filled and compacted when the earthing of power system completed which shows that the insulating value of clean crushed rock and gravel is an aid to safety under ground fault condition when an excavation in rock surfacing is applied it is necessary to avoid mixing with the surrounding rock surfacing material.[8][9]

3.1 Safety measures

Engineers to offer an individually designed the system to safe and responsible, therefore basic required information for good earthing for power system depends on two elevation systems. The resistivity data available and soil conditioning agents. Ingots of high purity copper and aluminum are friction welded together forming an effective electrical and mechanically robust joint. This termination is used for conjunction with contax inhibitor grease minimizes the effect of corrosion.[4][10]

4. Recommendations

As with the passage of time the condition of soil/gravel become as such that there was no gravel before at the guard this is because of gravel penetration into the soil or windstorm so gravel cleaning measurements should be made periodically for safety measures. Resistivity measurements should be taken during the year at regular intervals and taken worst condition of resistivity should be taken in earthing design. The earthing for power system is designed with correct choice of material and installation should be satisfactory for life span of at least 40 years.

5. Conclusions

Less fatal and non fatal accidents occur due to good earthing system. Attainable seldom calculation in the field. The potentials are measured when the network is loaded with high ampere. Those are the routine applications. The power engineers designs the earthing system to avoid the dangerous occurrence. So many factors be considers for safety purposes.

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