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Proceedings

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Yoanes Bandung (Institut Teknologi Bandung, Indonesia)
Suryono (Diponegoro University, Indonesia)

Program

Thursday, September 27

Thursday, September 27 9:30 - 11:30

INV: Invited Paper

Green Computing: Opportunity of Using Breadth Fixed Gossip Algorithm for Optimizing Power Supply Route in Power Plant
Mauridhi Purnomo (Institut Teknologi Sepuluh Nopember, Indonesia)
pp. 1-6

Thursday, September 27 13:00 - 15:15

A1: Electronic Circuit & Control

Magnetic Field Relationship between Distance and Induced Voltage Generated by EMP
Betantya Nugroho and Azli Yahya (Universiti Teknologi Malaysia, Malaysia); Abd Rahim (Mindmatics, Malaysia); Trias Andromeda (Universitas Diponegoro, Indonesia)
pp. 7-10

Communication Protocol on 64-Channel ECVT Data Acquisition System
Arbai Yusuf (Universitas Indonesia & C-Tech Labs Edwar Technology, Indonesia)
pp. 11-14

Cooling System Design Based on Thermoelectric Using Fan Motor on-off Control
Munnik Haryanti (Universitas Dirgantara Marsekal Suryadarma, Indonesia)
pp. 15-18

Design of The 3D Surface Scanning System for Human Wrist Contour Using Laser Line Imaging
Riky Tri Yunardi and Ario Imandiri (Universitas Airlangga, Indonesia)
pp. 19-23

Temperature Controlling Using PID Controller on Rice Grain Fluidized Dryer Prototype
Aris Triwiyatno (Diponegoro University, Indonesia)
pp. 24-27

PID Based Air Heater Controller Implemented With Matlab/Simulink and Arduino Uno
Bambang Supriyo, Dadi Dadi, Sulistyo Warjono, Adi Wisaksono, Sri Astuti and Kusno Utomo (Politeknik Negeri Semarang, Indonesia)
pp. 28-32

Design A Low Cost Wind Direction Sensor With High Accuracy
Yoga Utama (University of Widya Kartika, Indonesia)
pp. 33-38

Quadruped Robot with Stabilization Algorithm on Uneven Floor using 6 DOF IMU based Inverse Kinematic
Rofiq Prayogo (Diponegoro University, Indonesia)
pp. 39-44

Design and Characterization of Low-Cost Soft Pneumatic Bending Actuator for Hand Rehabilitation
Mochammad Ariyanto, Joga Setiawan, Rifky Ismail, Ismoyo Haryanto, Tania Febrina and Doni Saksono (Diponegoro University, Indonesia)
pp. 45-50

B1: Electric & Power System

Design and Performance Test of Three Phased SRF-PLL using DSPIC30F4011
Syarief Ali, Iwan Setiawan and Susatyo Handoko (Universitas Diponegoro, Indonesia)
pp. 51-56

The Effect of Excitation Capacitors on Induction Generators in Loss-of-Grid Events
Mokhammad Isnaeni Bambang Setyonegoro (Universitas Gadjah Mada, Indonesia); Danang Wijaya (UGM, Indonesia); Eka Firmansyah (Universitas Gadjah Mada, Indonesia)
pp. 57-60

Transient Stability Study in Grid Integrated Wind Farm
Samuel Adi Kusumo (Universitas Gadjah Mada, Indonesia); Lesnanto Multa Putranto (UGM, Indonesia); Tiyono Tiyono (Universitas Gadjah Mada, Indonesia)
pp. 61-66

Analysis of Energy Potential of Biomass Electricity from Leaf Waste by Using Briquette Method
Herlina Wahab (Sriwijaya University & University of Indonesia, Indonesia); Rudy Setiabudy (Universitas Indonesia (UI), Indonesia); Akbar Cahyadi (Universitas Indonesia, Indonesia)
pp. 67-72

DVR to Voltage Sag Mitigation Due to Induction Motor Starting and 3 Phase Fault
Muhammad Kuncoro and Iwa Garniwa (University of Indonesia, Indonesia)
pp. 73-78

A Single Phase 11-Level Inverter for Photovoltaic Application
Wira Adhitama and Leonardus Pratomo (Soegijapranata Catholic University, Indonesia)
pp. 79-83

Design and Implementation of Inverter Single Phase Nine-Level Using PIC18F4550
Natanael Novalutfi and Leonardus Pratomo (Soegijapranata Catholic University, Indonesia)
pp. 84-88

Energy Saving Measures and Potential of Energy Efficiency at The University of Surabaya
Fitri Kartikasari (University of Surabaya, Indonesia); Elieser Tarigan (University of Surabaya & Electrical Engineering, Indonesia); Yunus Fransiscus and Tuani Lidyawati (University of Surabaya, Indonesia)
pp. 89-92

Design and Simulation of an Asymmetrical 11-Level Inverter for Photovoltaic Applications
Christopher Tjokro and Leonardus Pratomo (Soegijapranata Catholic University, Indonesia)
pp. 93-98

C1: Information & Computer Technologies

MRI Image Segmentation using Morphological Enhancement and Noise Removal based on Fuzzy C-means
Robert Setyawan, Mustofa Alisahid Almahfud, Christy Atika Sari, De Rosal Ignatius Moses Setiadi and Eko Hari Rachmawanto (Dian Nuswantoro University, Indonesia)
pp. 99-104

Measurement on Real-Time Diagnostic of Gastric Tumor Model Using Wireless Endoscopy System
Novietasari Chisnariandini (University of Indonesia, Indonesia); Arie Pangesti Aji (Universitas Indonesia, Indonesia); Yudiansyah Yudiansyah (University of Indonesia, Indonesia); Prita Dewi Mariyam, Jauharul Fuadi, Yulianto La Elo and Basari Basari (Universitas Indonesia, Indonesia)
pp. 105-108

Relational Database Structure and Operations Engineering Based on UML Diagram
Lukman Hakim (Bandung Institute of Technology, Indonesia); Sukrisno Mardiyanto (Institut Teknologi Bandung, Indonesia)
pp. 109-113

Design of Secure IoT Platform For Smart Home System
Arvandy Arvandy and Yoanes Bandung (Institut Teknologi Bandung, Indonesia)
pp. 114-119

Marker Image Variables Measurement of Augmented Reality in Mobile Application
Ike Windasari, Yudi Windarto and Risma Septiana (Diponegoro University, Indonesia)
pp. 120-124

Sentiment Analysis and Topic Modelling for Identification of Government Service Satisfaction
Moh Nasrul Aziz, Ari Firmanto, Ahmad Miftah Fajrin and R. V. Hari Ginardi (Institut Teknologi Sepuluh Nopember, Indonesia)
pp. 125-130

Prototype of Online Examination on MoLearn Applications Using Text Similarity to Detect Plagiarism
Julianto Lemantara (Institut Bisnis dan Informatika Stikom Surabaya, Indonesia); Dewiyani Sunarto (Institute of Business and Informatic Stikom Surabaya, Indonesia); Bambang Hariadi, Tri Sagirani and Tan Amelia (Institut Bisnis dan Informatika Stikom Surabaya, Indonesia)
pp. 131-136

Performance Comparison Between AES256-Blowfish and Blowfish-AES256 Combination
Muhammad Muin (Universitas AMIKOM Yogyakarta & STMIK Bina Patria, Indonesia); Arief Setyanto (Universitas AMIKOM Yogyakarta, Indonesia); Sudarmawan Sudarmawan (AMIKOM Yogyakarta University, Indonesia); Kartika Santoso (STMIK Bina Patria, Indonesia)
pp. 137-141

A Natural Childbirth Training Simulation in Virtual Environment For Prospective Midwife
Alvin Nugraha, Aulia Faza, Wulan Indayani and Hanny Haryanto (Universitas Dian Nuswantoro, Indonesia); Abas Setiawan (Dian Nuswantoro University, Indonesia)
pp. 142-146

D1: Telecommunications & Radio Frequency

Study on 2G Termination in Indonesia using BCG Matrix
Alaind Fadrian and Ajib S. Arifin (Universitas Indonesia, Indonesia)
pp. 147-151

Performance of 8FSK base on PACTOR I protocol over AWGN channels
Mohd Yazid Ab Razak (National University of Malaysia & Mindmatics Sdn Bhd, Malaysia); Abd Rahim Mat Sidek (Mindmatics Sdn Bhd, Malaysia); Nasharuddin Zainal (Universiti Kebangsaan Malaysia, Malaysia)
pp. 152-156

Development of Radio Direction Finder using 6 Log Periodic Dipole Array Antennas
Kartiko Nugroho, Azli Yahya and Nor Hisham Khamis (Universiti Teknologi Malaysia, Malaysia); Nuramirah Mohd Nor (Mindmatics Sdn. Bhd., Malaysia); Abd Rahim (Mindmatics, Malaysia); Mohammad Razman Shaari (Mindmatics Sdn. Bhd., Malaysia)
pp. 157-160

Directional 2x2 MIMO Microstrip Antenna Design and Optimization for LTE Band-3 Application
Tommi Hariyadi and Rizky Megantara (Universitas Pendidikan Indonesia, Indonesia)
pp. 161-166

High Throughput Wireless Printer Server Based on IEEE 802.11n
Wahyul Amien Syafei (Diponegoro University, Semarang & Kyushu Institute of Technology, Iizuka, Indonesia); Imam Santoso (Diponegoro University, Indonesia)
pp. 167-170

Analysis on Batik Water Waste Monitoring System based on LoRa Communication
Michael Stephen Moses Pakpahan, Eko Didik Widianto and Risma Septiana (Diponegoro University, Indonesia)

pp. 171-175

A GIS-based Waste Water Monitoring System Using LoRa Technology
Yudi Windarto and Agung Prasetijo (Diponegoro University, Indonesia); Galang Damara (Universitas Diponegoro, Indonesia)
pp. 176-179

Filtering for Data Aquisition on Wireless Sensor Network
Aghus Sofwan, Sumardi Sumardi and Nely Ulwiyati (Diponegoro University, Indonesia)
pp. 180-184

Thursday, September 27 15:30 - 17:30

A2: Electronic Circuit & Control

Predictive Control for Relative Performance Management
Dharma Aryani (State Polytechnic of Ujung Pandang, Indonesia); Nur Asyik Hidayatullah (State Polytechnic of Madiun, Indonesia)
pp. 185-190

Design and Development of Injection Current Control On Inverter-Based Proportional Resonant Method
Abdul Haris Kuspranoto and Iwan Setiawan (Universitas Diponegoro, Indonesia); Mochammad Facta (Diponegoro University, Indonesia)
pp. 191-196

Development of Object Tracking System Using Remotely Operated Vehicle Based on Visual sensor
Erwin Saputra and Ronny Mardiyanto (Institut Teknologi Sepuluh Nopember, Indonesia)
pp. 197-202

Predictive Control Approach for Restricted Areas Avoidance of Autonomous System
Sutrisno Sutrisno, Widowati Widowati, Sunarsih Sunarsih and Kartono Kartono (Diponegoro University, Indonesia)
pp. 203-207

Kufarm: A Modified Platform of Automation Planting System
Damar Pramuditya (Telkomuniversity, Indonesia); Agung Nugroho Jati and Fairuz Azmi (Telkom University, Indonesia)
pp. 208-213

Tracking Object based on GPS and IMU Sensor
Wahyudi Wahyudi (Department of Electrical Engineering, Diponegoro University)
pp. 214-218

Development of Navigation Method of Buoyant Boat for Maintaining Position of The Boat and ROV
Ronny Mardiyanto, Heri Suryoatmojo and Badrut Tamam (Institut Teknologi Sepuluh Nopember, Indonesia)
pp. 219-224

Development of a Low-Cost Quadrupedal Starfish Soft Robot
Mochammad Ariyanto, Munadi M and Joga Setiawan (Diponegoro University, Indonesia)
pp. 225-229

Performance Improvement of Robot Warehouse Based on Battery Operational Conditions
Almira Budiyanto, Aris Setiawan and Setyawan Wahyu Pratomo (Universitas Islam Indonesia, Indonesia)
pp. 230-233

B2: Electric & Power System

Design of Adaptive PID Controller for Fuel Utilization In Solid Oxide Fuel Cell
Darjat Darjat, Sulistyo Sulistyo and Aris Triwiyatno (Diponegoro University, Indonesia)
pp. 234-239

Study on Photovoltaic Hosting in Yogyakarta Electric Distribution Network
Faishal Fuad Rahman Soeharto (Universitas Gadjah Mada, Indonesia); Kristianto Adi Widiatmoko and Sarjiya Sarjiya (Gadjah Mada University, Indonesia); Lesnanto Multa Putranto (UGM, Indonesia)
pp. 240-244

Analysis of Grounding System in 150 kV Kudus Substation
Riza Pratama, Hermawan Hermawan and Mochammad Facta (Diponegoro University, Indonesia)
pp. 245-250

Maximum Power Tracking of Solar Panel using Modified Incremental Conductance Method
Trias Andromeda (Universitas Diponegoro, Indonesia); Betantya Nugroho (Universiti Teknologi Malaysia, Malaysia); Susatyo Handoko (Universitas Diponegoro, Indonesia); Azli Yahya (Universiti Teknologi Malaysia, Malaysia); Hermawan Hermawan and Mochammad Facta (Diponegoro University, Indonesia); Iwan Setiawan (Universitas Diponegoro, Indonesia)
pp. 251-255

Electrical Load Forecasting Study Using Artificial Neural Network Method for Minimizing Blackout
Husein Mubarok and Mukhamad Sapanta (Universitas Islam Indonesia, Indonesia)
pp. 256-259

Comparison Study on Leakage Current of 20 kV Silicon Rubber and Epoxy Resin Insulator Under Dry and Wet Condition
Taryo Taryo (Diponegoro University, Indonesia); Abdul Syakur (Universitas Diponegoro, Indonesia); Hermawan Hermawan (Diponegoro University, Indonesia)
pp. 260-263

Leakage Current Characteristics of 20 kV Epoxy Resin Insulators Under Variation Humidity
Pertiwi Utami and Hermawan Hermawan (Diponegoro University, Indonesia); Abdul Syakur (Universitas Diponegoro, Indonesia)
pp. 264-267

Measurement System for Surface Leakage Current at Epoxy Resin Insulating Materials
Abdul Syakur (Diponegoro University, Indonesia); Wahyudi Wahyudi (Departemen Teknik Elektro UNDIP, Indonesia); Jumrianto Jumrianto, Jr (Diponegoro University & NET TV, Indonesia)
pp. 268-271

An Investigation of Direct Grounding Effect on Modeling of Lightning and Tower in Transmission Line
Mochammad Facta, Abdul Syakur and Hermawan Hermawan (Diponegoro University, Indonesia)
pp. 272-275

C2: Information & Computer Technologies

Halstead Metric for Quality Measurement of Various Version of Statcato
Iwan Binanto (Sanata Dharma University, Indonesia); Bahtiar Saleh Abbas and Nesti Sianipar (Bina Nusantara University, Indonesia); Harco Leslie Hendric Spits Warnars (Bina Nusantara University & Doctor of Computer Science, Indonesia)
pp. 276-280

Environmental Health Monitoring with Smartphone Application
Kodrat Iman Satoto, Eko Didik Widianto and Sumardi Sumardi (Diponegoro University, Indonesia)
pp. 281-286

Two-Step Ranking Document Using the Ontology-Based Causality Detection
A. A. I. N. Eka Karyawati and L. A. A. Rahning Putri (Udayana University, Indonesia)
pp. 287-292

Knowledge Management Model in Syariah Banking
Nurdin Nurdin (Institut Agama Islam Negeri Palu); Sagaf S Pettalongi and Khaeruddin Yusuf (Institut Agama Islam Negeri Palu, Indonesia)
pp. 293-298

The Spreading of Misinformation online: 3D Simulation
Pardis Pourghomi and Milan Dordevic (American University of the Middle East, Kuwait); Fadi Safieddine (Queen Mary University of London, United Kingdom (Great Britain))
pp. 299-304

IT Management Flexibility Concept for Higher Education
Wasilah Wasilah (Gajah Mada University (UGM) & Informatics and Bisniss Institute (IBI DARMAJAYA) Bandar Lampung, Indonesia); Lukito Edi Nugroho and Paulus Insap Santosa (Universitas Gadjah Mada, Indonesia)
pp. 305-309

Review on Cost-Value Approach for Requirements Prioritization Techniques
Tan Amelia (Institut Bisnis dan Informatika Stikom Surabaya, Indonesia); Rozlina Mohamed (Universiti Malaysia Pahang, Malaysia)
pp. 310-314

Critical Success Factor of Information Technology Implementation in Supply Chain Management
Erick Fernando and Surjandy Surjandy (Bina Nusantara University, Indonesia); Harco Leslie Hendric Spits Warnars (Bina Nusantara University & Doctor of Computer Science, Indonesia); Meyliana Meyliana (Bina Nusantara University, Indonesia); Raymond Kosala (Faculty of Computing & Media, Indonesia); Edi Abdurachman (Bina Nusantara University, Indonesia)
pp. 315-319

The Evaluation of Child's Health Monitoring System Using the Usability Testing Approach
Kurniawan Martono (Diponegoro University, Indonesia)
pp. 320-324

D2: Information & Computer Technologies

Ticketing Chatbot Service using Serverless NLP Technology
Eko Handoyo and M Arfan (Diponegoro University, Indonesia); Yosua Alvin Adi Soetrisno (Diponegoro University & Faculty of Engineering, Indonesia); Maman Somantri, Aghus Sofwan and Enda Wista Sinuraya (Diponegoro University, Indonesia)
pp. 325-330

Design of Water Quality Control for Shrimp Pond Using Sensor-Cloud Integration
Maman Somantri, Aghus Sofwan, M Arfan, Vivi Endar Herawati and Hafiidhin Abdurrasyiid (Diponegoro University, Indonesia)
pp. 331-335

A Comparative Study of Image Cryptographic Method
De Rosal Ignatius Moses Setiadi, Eko Hari Rachmawanto and Christy Atika Sari (Dian Nuswantoro University, Indonesia); Ajib Susanto (Universitas Dian Nuswantoro, Indonesia); Mohamed Doheir (Universiti Teknikal Malaysia Melaka, Malaysia)
pp. 336-341

Handwriting Ownership Recognition using Contrast Enhancement and LBP Feature Extraction based on KNN
Nurul Diyah Ayu Partiningsih, Rizki Ramadhan Fratama, Christy Atika Sari, De Rosal Ignatius Moses Setiadi and Eko Hari Rachmawanto (Dian Nuswantoro University, Indonesia)
pp. 342-346

Comparison of HSV and LAB Color Spaces for Hydroponic Monitoring System
Thomas Agung S and Setyo Aji Riwinanto (Politeknik Negeri Semarang, Indonesia); Suhendro S (Politeknik Negeri Semarang, Indonesia); Helmy Helmy and Arif Nursyahid (Politeknik Negeri Semarang, Indonesia); Ari Sriyanto Nugroho (Politeknik Negeri Semarang, Indonesia)
pp. 347-352

Automatic Docking Based on Visual Feedback on Remotely Operated Vehicle
Muhammad Qomaruzzaman and Ronny Mardiyanto (Institut Teknologi Sepuluh Nopember, Indonesia)
pp. 353-358

Performance Improvement of Human Activity Recognition based on Ensemble Empirical Mode Decomposition
Enda Wista Sinuraya (Diponegoro University, Indonesia); Yosua Alvin Adi Soetrisno (Diponegoro University & Faculty of Engineering, Indonesia); Denis Denis (Diponegoro University, Indonesia); Aminuddin Rizal (National Taiwan University of Science and Technology, Taiwan)
pp. 359-364

Naive Bayes Classifier For Prediction Of Volcanic Status In Indonesia
Firman Tempola (Universitas Khairun Ternate, Indonesia)
pp. 365-369

Case Based Reasoning For Determining The Feasibility Of Scholarship Grantees Using Case Adapatation
Firman Tempola (Universitas Khairun Ternate, Indonesia)
pp. 370-374

A Development of Executive Information Based on Satisfaction Level of Students
Mochammad Facta, Eflita Yohana, Karina Adhiriva and Awalina Sayekti (Diponegoro University, Indonesia)
pp. 375-378

Compressive Sensing Approach with Double Layer Soft Threshold for ECVT Static Imaging
Nur Afny Catur Andryani (Tanri Abeng University & University of Indonesia, Indonesia); Dodi Sudiana and Dadang Gunawan (Universitas Indonesia, Indonesia)
pp. 379-384

Context-based Hydrology Time Series Data for A Flood Prediction Model Using LSTM
Indrastanti Ratna Widiasari (Satya Wacana Christian University & Universitas Gadjah Mada, Indonesia)
pp. 385-390

Design and Performance Test of Three Phased Synchronous Reference Frame-Phase Locked Loop (SRF-PLL) using DSPIC30F4011

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Abstract-*a Phase Locked Loop (PLL) is widely used for synchronizing between grid-connected inverter systems with the utility grid. Ideally, the PLL should estimate grid voltage information accurately. The aim of this research is to design and implement the popular Synchronous Reference Frame – Phase Locked Loop (SRF-PLL) to estimate phase, magnitude and frequency of the three phase grid voltage. In this work, the PLL algorithm is embedded in the 16 bit wide dsPIC30F4011 microcontroller where the time sampling used to execute the algorithm is 0.1 ms. For analysis purposes, the estimated grid voltage parameters are then sent to DAC AD7302 to observed by oscilloscope. Based on experimental result, the realized algorithm could estimate the three phase grid voltage parameters accurately*

Keywords-Voltage Sensor, SRF-PLL, dsPIC30f4011

I. INTRODUCTION

Phase Locked Loop **(**PLL**)** is widely used in synchronization between *Grid-Side Converters* (GSC) and grids. Grid-tie inverters play big role in GSC system and improvement. This device is now one very popular in connecting renewable energy power plan and grids[1]. The world's demand of energy has increased and pushed human being to do research to generate renewable energy power plants such as Solar power. Since the power generated by photovoltaic systems are DC voltages, inverters are used to convert DC voltages to AC voltages then the AC power transfered to enrich and supports the grids. In this step, PLL is used to gain information for power synchronization[2], [3].

Ideally, PLL will provide fast and accurate power information and not easily disturbed by noise, harmonics, unbalanced, and any other distortions.

Synchronous Reference Frame Phase Locked Loop (SRF-PLL) is a kind type of PLL. SRF-PLL is type of PLL which is best to find information in balanced grids condition. According to Saritha Natesan's and Jamuna Venkatesan's paper[4], SRF-PLL is very good to be used to read balanced grids. PI control method is used because its characteristics to have fast response to any system movements or changes. This characteristics is very match and suitable for PLL as it's used to obtain critical synchronization data[1], [5].

There are many theories and methods proposed to build phase locked loop. Basically, the difference between single phased PLL and three phased PLL is single phased PLL need an additional signal for the input of Park transformations as Park theory needs two inputs (Vα and Vβ). The other way to deal with single phased PLL is to set the Vβ value into 0 and this method called "Constant Zero Orthogonal Component"[6]. Since the Park transformation required two inputs, other method generate the other signal by delaying the first signal by T/4 period delay[7]. However, to build three phased PLL, additional signal generator is not necessary as Vα and Vβ are obtained from Phase A and Phase B voltage or Phase B and Phase C because these combination has 90º angle lag (orthogonal).

II. GENERAL CONCEPT OF SRF-PLL

SRF-PLL consists of 3 mathematical processes known as Clarke transformation, Park transformation, and SRF-PLL algorithm itself. Clark transforms Va, Vb, and Vc into Vα and Vβ. The values of Vα and Vβ gained from Clarke transformation are transformed once again into Vd and Vq using Park transformation method. The Mathematical formulas of Clarke transformation written as follows[2][8]:

$$I_\alpha = I_a \quad (1)$$

$$I_\beta = \frac{1}{\sqrt{3}}(I_a + 2I_b) \quad (2)$$

And the Park transformation formulas are[2]

$$I_\mathrm{d} = I_\alpha * \cos(\theta) + I_\beta * \sin(\theta) \quad (3)$$

$$I_q = I_\beta * \cos(\theta) - I_\alpha * \sin(\theta) \quad (4)$$

Vd represents the magnitude of real voltage value and Vq represents the vector of the voltage phase. The value of Vq should be around zero. Vq then become the input value of SRF-PLL subsystem to detect phase angle. The block diagram of SRF-PLL is shown in Fig. 1

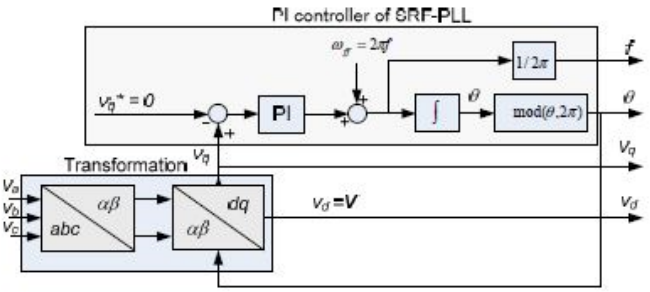


Fig.1. SRF-PLL Block Diagram[2]

III. SYSTEM MODEL AND DESIGN

A. *Hardware Design*

The hardware used in this device are voltage sensor, DAC AD7302, and dsPIC30F4011 microcontroller minimum system. DSPIC30F4011 microcontroller is chosen because its settle ability to process signal and specially engineered as digital signal processor[9], [10]. Before SRF-PLL design is made, the block diagram is shown at Fig. 1 and the steps are determined as follows:

1. The three phased voltage source (as an input) is connected to the voltage sensor.
2. The voltage sensor circuit is used for signal conditioner so that the voltage could be read by the microcontroller DSPIC30F4011
3. Microcontroller 16-Bit dsPIC30f4011 is used to run the SRF-PLL algorithm. The SRF-PLL algorithm are *Clarke* dan *Parke* transformation, PI control system, and feedback.
4. Computer is used to make SRF-PLL program code using MPLAB and PICkit 2 is used to build the code into DSPIC30F4011.
5. DAC AD7302 is used to convert digital data from the algorithm into analog typed data so that the data can be displayed in the oscilloscope.
6. Oscilloscope is used to display all SRF-PLL data.

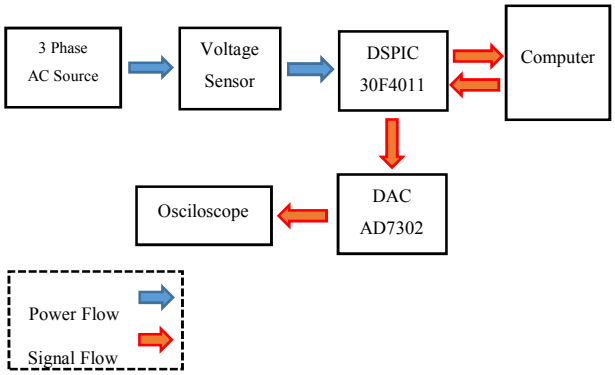


Fig.2. System Block Diagram

B. *Voltage Sensor*

The power source in this research is three phased AC voltage each phase is 230 Vac and 50 Hz obtained from High Voltage Laboratory, Universitas Diponegoro, Semarang will be connected to the sensor and the signal will be processed by voltage sensor. Each phase voltage R, S, and T measured around 220-230 Volt. The components selected to build Voltage sensor are 3 pcs *step down* transformers, 9 pcs 10K Ω resistors, 3 pcs 2.2K Ω resistors, 3 pcs 50KΩ multi-turn potentiometers, and 3 pcs 20KΩ multi-turn potentiometers. Figure 3 shows the schematic circuit.

Fig.3. Three Phased Voltage Sensor

Before tuning, the voltage sensor should be calibrated. In this project, the base value of voltage input is set to 230 rms or 325 Vp. The base value is chosen from voltage range in laboratory and will be used in fixed-point arithmetic. The fixed-point arithmetic method is used to ease the programming process.

Voltage sensor is designed to manually tune the input signal into 0-5 Vdc signal. This DC signal will be processed by microcontroller in SRF-PLL algorithm.

Table 1. Voltage Sensor Circuit Specification

Parameters	Value
Transformer type	*Step down*
Input Voltage Rate	230 VAC
Output Voltage Rate	12 VAC
Op-Amp (LM324N)	V_{in} : 1.5 – 16 V

Table 1 shows the components used for sensor circuit. Input voltage 230 volt stepped down to 4.5 volt (in the other words, the input voltage now is sine wave from -4.5 to 4.5 volt). The Op-Amp and variable resistors will strengthen the output voltage. Voltage wave combinations are adjustable between 0 to 5 volt depends on voltage's condition.

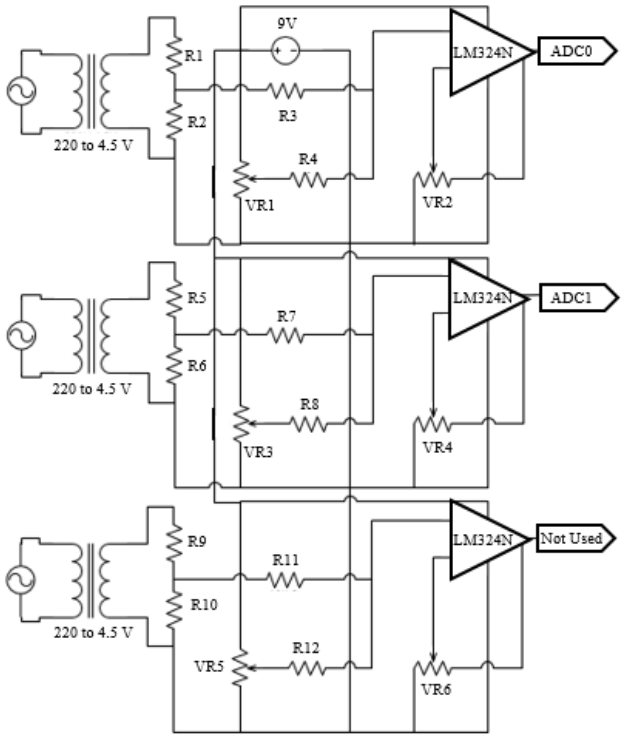


Fig.4. Schematic Circuit of Three Phased Voltage Sensor

Note:
R1, R3, R4, R5, R7, R8, R9, R11, R12 : 10KΩ
R2, R6, R10 : 2.2KΩ
VR1, VR3, VR5 : 20KΩ
VR2, VR4, VR6 : 50KΩ

C. *Digital To Analog Converter* (DAC)

In this project, Digital to Analog Converter (DAC) used to display output phase wave, frequency, and magnitude to oscilloscope is AD7302 parallel DAC. AD7302 is selected based on its ability to simultaneously process two data[11].

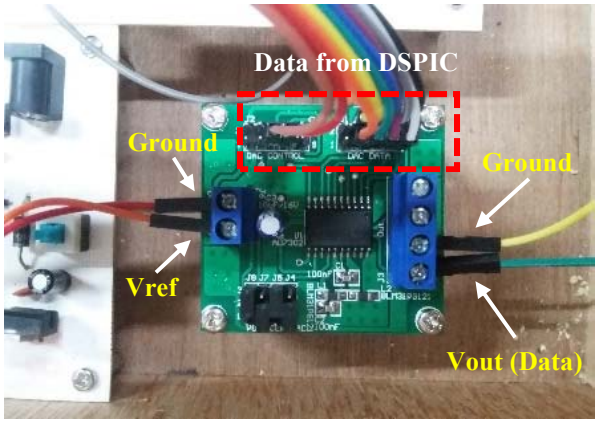


Fig.5. Digital to Analog Converters (AD7302)

D. *SRF-PLL Program*

The programming concept chosen to build SRF-PLL is fixed-point arithmetic method. Basically, all data were converted to fixed-point mantissa which is between 0 to 65535 in 16 bit data. Voltage, phase angle, Clarke and Park transformation data defined as signed integer and frequency data as unsigned integer and all data are converted into per unit form. The conversion to per unit form is done to make the calculation process faster and easier.

The formula used to transform the value to per unit form and to 16 bit mantissa fixed-point form are

$$Xpu = \frac{X}{Base\ X}) \quad (5)$$

$$M = Xpu\,.2^{16} \quad (6)$$

Where,

Xpu = per unit value
X = Actual value
Base X = Highest range of X possibly
M = Mantissa
2^{16} = 16 bit data form

E. *Lookup table*

In this project, the lookup table capacity is 8 bit (256 data sections) represents shifting point angles. If the value of an angle in one cycle is 2π, to build 256 data of sine table, each shifting point angle should be divided by 256 then the formulas could be written as follows.

$$\Delta\theta = \frac{2\pi}{256} = 0{,}0245\ rad \quad (7)$$

In degree,

$$\Delta\theta = 0{,}0245 \times \frac{180^\circ}{\pi} = 1{,}40625^\circ \quad (8)$$

And the sine table data can be obtained by

$$\sin(1{,}40625^\circ) = 0{,}0245 \quad (9)$$

This is the example to get the first and the second data in lookup table.

$$Data_1 = 1 \cdot 0{,}245 \cdot 32768 = 804{,}167 \approx 804 \quad (10)$$

$$Data_2 = 2 \cdot 0{,}245 \cdot 32768 = 1608{,}33 \approx 1608 \quad (11)$$

F. PI controller

Since all data are converted to 16 bit fixed-point form, the value of P and I controller gains possible are also between 0 – 1. The gain values obtained by empirical method. The less value of Ki will lead to better result although the value of Kp and Ki will not give significant impact to the system due to feed forward bias control (ω_f)[1], [2], [7].

IV. EXPERIMENT RESULT AND DISCUSSION

Before testing the hardware, the input voltage should be set as balanced grid condition, the phase angle of each phase R, S should've been checked, and the voltage sensor must be calibrated. These data are determined to do the hardware testing.

Table.2 Testing variable

Variable	Value
Voltage Input Phase R,S	225, 227 Volt
Transformer Output Value	4.5 Volt
Bias Frequency value	49 Hz
Vd base value (in code)	321 Volt
Base frequency value (in code)	51 Hz
Kp	0.99
Ki	0.1

A. SRF-PLL hardware

The result of this project is a complete system of SRF-PLL that consist of a SRF-PLL program in the laptop, Voltage sensor, and an oscilloscope to display the wave forms. Fig.6 shows the complete SRF-PLL system.

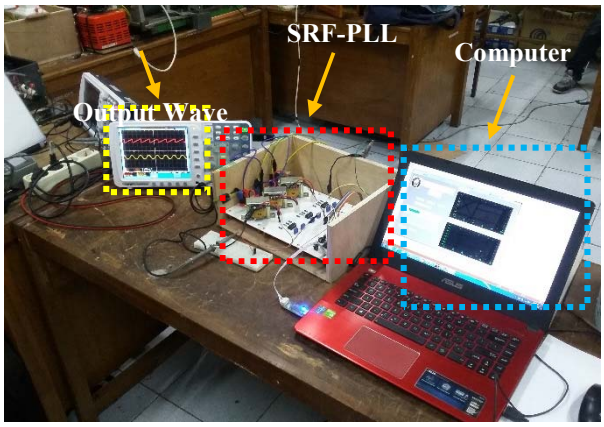


Fig.6. Completed SRF-PLL device

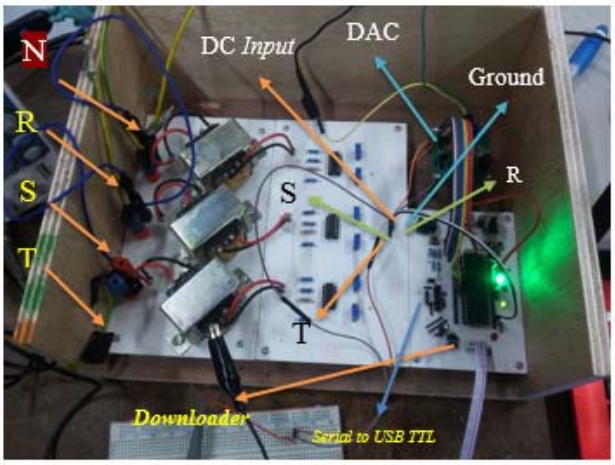


Fig.7. Voltage Sensor Circuit

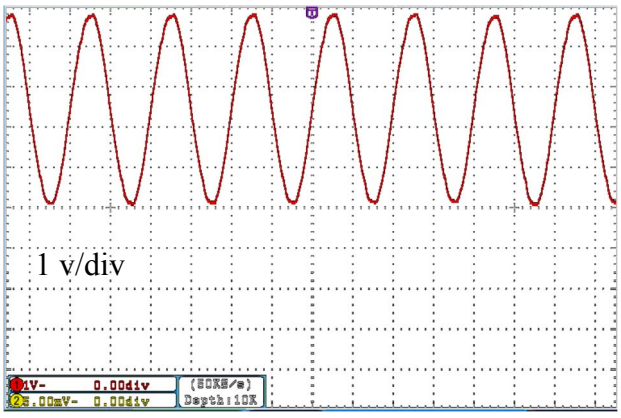


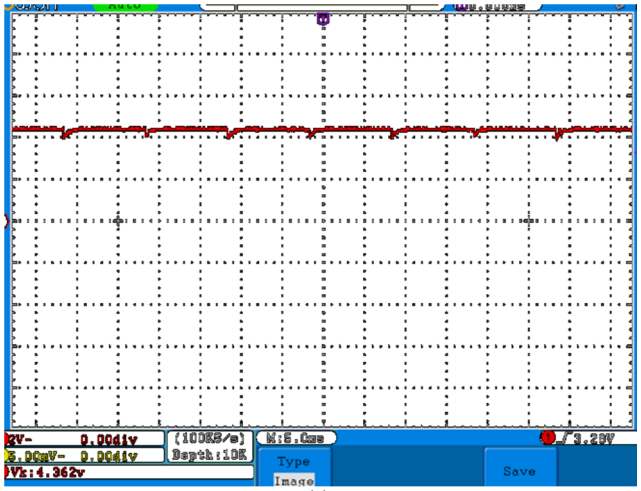
Fig. 8 Input signal wave

Voltage sensor is used to set the initial value or wave range for the input. This device is designed in three segments and each segment represents phase R, S, and T. Fig. 7 Shows the details of the SRF-PLL circuit.. The input requirements for the system is sine wave between 0

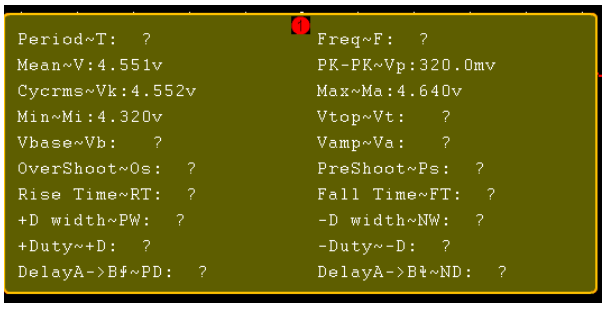
to 5. The input can be modified by adjusting the potentiometer for each segment. Fig. 8 shows the input signal wave generated from voltage sensor. In this SRF-PLL program, 0 represents -32767 and 5 represents 32767 therefore the mid point 2.5 represents 0 in lookup table. These number formation will faster the calculation proccess.

B. *Voltage Magnitude*

Magnitude voltage is one of three outputs obtained from SRF-PLL. Fig.10 shows magnitude voltage value in between 0 to 5 volt. The wave form is almost flat overall. This shows a good result where based on the theory, magnitude wave form should be flat or stable. Some glitch are normal due to poor sensor's accuracy and also the input voltage value change anytime in the laboratory. The ideal value of output should be 321 volt as the base voltage for this system is 230 volt ($230\sqrt{2} = 321$ volt).



(a)



(b)

Fig.9 (a) Magnitude from SRF-PLL (b) Wave information

The formulas to obtain the actual magnitude value as follows:

$$\frac{Vmax\ Osciloscope}{Vmax\ Sensor} x\ 321\ Volt \qquad (12)$$

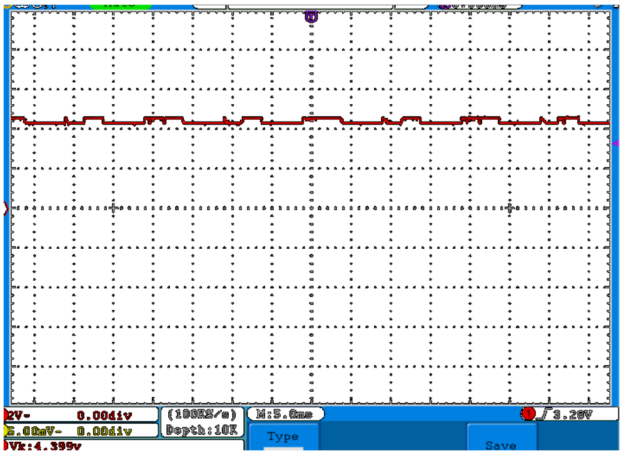
$$\frac{4.64}{4.71} x\ 321\ Hz = 318{,}256\ Volt$$

Where,

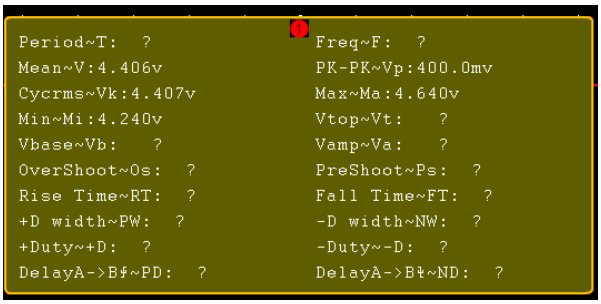
Vmax Oscilloscope	: Data from Oscilloscope
Vmax Sensor	: Voltage reference from dsPIC
321 volt	: Voltage base

C. *Frequency*

Fig.11 shows the output frequency data from SRF-PLL. Although the result is fluctuate, this data is correct because the information needed is the maximum voltage value.



(a)



(b)

Fig.10 (a) Frequency from SRF-PLL (b) Wave information

The frequency read by SRF-PLL is around 50.24 Hz. The formulas to obtain the actual frequency value as follows:

$$\frac{Vmax\ Osciloscope}{Vmax\ Sensor} x\ 51\ Hz \qquad (13)$$

$$\frac{4.64}{4.71} x\ 51\ Hz = 50.24\ Hz \qquad (14)$$

Where,

Vmax Oscilloscope	: Data from Oscilloscope
Vmax Sensor	: Voltage reference from dsPIC
Voltage base	: 321 Volt

D. Phase Angle

Fig.13 shows the phase wave result with input V-R input. Phase wave represents input wave's phase angle position. When the value of voltage is maximum (maximum amplitude), the phase wave will be in the lowest point. The maximum and minimum value of phase angle will be in the same position thus 0 and 2π are in the same place.

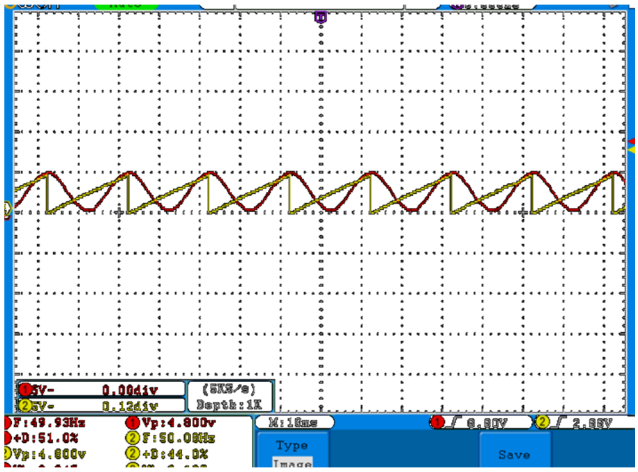


Fig.11. Phase angle and phase R input voltage

The maximum value of the wave is the value of dsPIC's voltage reference and the minimum wave point is the minimum input voltage value. As shown in the figure, the "saw waves" are match with the actual waves which means SRF-PLL successfully represents the actual voltage conditions.

V. CONCLUSION

In this project, SRF-PLL hardware based on dsPIC 30F4011 microcontrollers can work properly. SRF-PLL shows a good result and successfully proof the theory that this kind of PLL work the best in balanced grid condition. This device can extract Magnitude, frequency, and phase angle information in real time operation using dsPIC microcontroller which is specially build for RTO operation and inverter usage. However, to be implemented in real grids, the voltage sensor must be replaced or fixed because the existing sensor isn't robust enough. Besides, other types of PLL recommended are DSRF PLL or DSOGI PLL if the grid condition is unbalanced.

ACKNOWLEDGEMENT

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CERTIFICATE

This is to certify that

Syarief Ali

has contributed as

Presenter

in The 5th International Conference on Information Technology, Computer and Electrical Engineering (ICITACEE) 2018
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